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STANDARD SPECIFICATIONS FOR STRUCTURAL STEEL—TIMBER—CONCRETE AND REINFORCED CONCRETE

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STANDARD SPECIFICATIONS

FOR

STRUCTURAL STEEL—TIMBER—CONCRETE
AND REINFORCED CONCRETE

BY

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PREFACE

A SERIOUS attempt has been made to incorporate into one volume a set of ten specifications, which not only cover the most important materials used in construction work of any magnitude, but which are condensed so as to avoid unnecessary repetitions, are consistent throughout, and which, at the same time, conform in every essential to the latest experiments and investigations, to the best authorities, to modern practice, and to the author's own considerable experience.

Of new matter, particular attention is called to the specifications for REINFORCED CONCRETE, as these are rather extensive, probably the first complete set in existence.

To facilitate the use of all specifications, the subject matter in each has been arranged, as nearly as possible, in the order, or rotation, in which the information is wanted.

Any designs made, or structures built in strict accordance with these specifications will insure first-class details, excellent materials, and creditable workmanship, as well as safety, durability, and economy. Hence they are designed to be equally well suited to the needs of engineers, architects, contractors, college professors and their students.

In the body of the specifications credit has been accorded to authorities, when quoted, to whom thanks are due. Thanks are also due to Francis P. Wittmer, M. Am. Soc. C.E., and others for many valuable suggestions. J. C. O.

NEW YORK, September, 1910.

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STANDARD SPECIFICATIONS FOR STRUCTURAL STEEL—TIMBER—CONCRETE AND REINFORCED CONCRETE

PART I

STEEL FRAMEWORK OF BUILDINGS

Dead, Snow, and Wind Loads

1. **The Dead Load** upon any part of a structure shall consist of the calculated weight of the materials and fixtures carried permanently by such part.

2. The actual weight of the different materials shall be computed as accurately as possible and, if necessary, a trial design shall be made to ascertain the weight of any portion in doubt.

3. **Roof Covering.** The weight of roof covering will average, for each square foot of superficial roof area, as follows:

Corrugated steel	2–3	lbs.
Shingles	4–6	"
Roofing tiles	6–8	"
Slate ($\frac{1}{8}$ to $\frac{1}{4}''$ thick)	6–8	"
Gravel and composition	8–10	"
Terra-cotta, 2″ thick (flat arch)	10–15	"
Concrete, per inch thickness (flat arch)	10–12	"
Plank sheathing, per inch thickness	3–4	"

4. Purlins. The weight of purlins will average, for each square foot of superficial roof area, as follows:

Steel purlins.	2–3	lbs.
Wooden purlins.	3–5	"

5. Roof Trusses. The weight of ordinary steel roof trusses, having a pitch of $\frac{1}{5}$ to $\frac{1}{3}$, will average, for each square foot of horizontal area, as follows:

$$w = \frac{c}{800}(L+10),$$

or for the total weight of *one truss*,

$$W = \frac{cdL}{800}(L+10),$$

where W = total weight of truss in lbs.

c = weight in lbs. per sq.ft. on horizontal area carried by truss.

d = distance in feet between trusses, provided that $d \geqq \frac{L}{5}$ (Par. 23).

L = span in feet of truss.

6. Snow Load. In latitudes between 40° and 50° the snow load shall be taken per horizontal square foot of roof area as follows:

Pitch from flat to $\frac{1}{5}$ inclusive	. . . .	25	lbs.
" over $\frac{1}{5}$ to $\frac{1}{4}$ "	. . . .	20	"
" " $\frac{1}{4}$ to $\frac{1}{3}$ "	. . . .	15	"
" " $\frac{1}{3}$ to $\frac{1}{2}$ "	. . . .	10	"
" " $\frac{1}{2}$ and more	. . . .	0	"

In other latitudes these snow loads should be modified according to local conditions.

7. Wind Pressure. The wind pressure shall be taken as 30 lbs. per sq.ft., upon the entire exposed area of the steel framework, or upon the vertical projection of sides and ends of roof and building, and as acting horizontally in any direction.

8. Minimum Roof Load. The minimum roof load, which will include the dead, snow, and wind loads, shall be taken as follows:

On roof covering and purlins, 40 lbs. per sq.ft. of superficial area.
On roof trusses, 40 lbs. per sq.ft. of horizontal area.

Live Loads

9. Live Loads on Floors.

(*a*) The live loads on floors shall be considered as being uniform over their entire area and shall be taken, as a minimum, per square foot as follows:

Dwellings, apartment houses, hotels, hospitals	50 lbs. and up
Office buildings	60 "
Schools, theaters, churches	75 "
Ordinary stores, public buildings	100 "
Warehouses, factories, armories	200 "

When designing flooring, joists, girders, etc., the probability of concentrated loads, such as pianos, safes, machinery, wagons, etc., must be considered and provided for.

(*b*) The above live loads, except in warehouses and other buildings exposed to simultaneous loading on all floors, may be reduced for columns as follows:

Columns supporting roof and top floor, no reduction.
" " next ten floors, a cumulative reduction of 5 per cent for each succeeding floor.
" " remaining floors, a total reduction of 50 per cent.

10. Crane Loads. The actual weight of the crane, its dimensions and its lifting capacity shall be used if obtainable, otherwise the following data for Typical Electrical Traveling Cranes* shall be used:

* Mr. C. C. Schneider in Trans. Am. Soc. C. E., Vol. 54.

Capacity.	Span.	Wheel Base. Ft. In.	Maximum Wheel Load in Pounds.	s. Inches.	v. Feet.	Weight of Rail per Yard for Plate Girders. Pounds.	Beams. Pounds.
5 Tons	40	8 6	12,000	10	7	40	40
	60	9 0	13,000	10	7	40	40
10 "	40	9 0	19,000	10	7	45	40
	60	9 6	21,000	10	7	45	40
15 "	40	9 6	26,000	10	7	50	50
	60	10 0	29,000	10	7	50	50
20 "	40	10 0	33,000	12	8	55	50
	60	10 6	36,000	12	8	55	50
25 "	40	10 0	40,000	12	8	60	50
	60	10 6	44,000	12	8	60	50
30 "	40	10 6	48,000	12	8	70	60
	60	11 0	52,000	12	8	70	60
40 "	40	11 0	64,000	14	9	80	60
	60	12 0	70,000	14	9	80	60
50 "	40	11 0	72,000	14	9	100	60
	60	12 0	80,000	14	9	100	60

where s = Side clearance from center of rail.
v = Vertical clearance from top of rail.

(*a*) A wheel-load shall be assumed as distributed in the top flange, over a distance equal to depth of girder, with a maximum of 30 inches.

(*b*) In addition to the vertical load, the top flanges of the girder shall withstand a lateral loading of two-tenths ($\frac{2}{10}$) of the lifting capacity of the crane, equally divided between the four wheels of the crane.

11. Impact Loads. For beams, girders, and columns carrying traveling cranes an allowance of 25 per cent of the computed moments and shears due to same shall be added to compensate for the effects of impact and vibration.

Unit Stresses: Steelwork

12. In designing the component parts of any building the maximum stresses due to the combined effects of axial stresses and bending stresses from dead, snow, wind and live loads, including impact, if any, shall not exceed, for structural steel and rivet steel, the following values in *lbs. per square inch*, except as modified in Pars. 14–16.

(*a*) *Axial tension* in main members, net section	16,000	lbs.
" in wind bracing, "	20,000	"
(*b*) *Bending*, net section, on extreme fibers of:		
Rolled shapes, built sections and plate girders..................	16,000	lbs.
Pins........................	20,000	"

(*c*) *Axial compression* in main members, gross section,

$$S = 16{,}000 - 70\frac{l}{r},$$

where S = allowable unit stress.
l = unsupported length of member in inches.
r = least radius of gyration of member in inches. (Par. 39.)

(*d*) *Shear on:* Turned bolts, and field rivets when hand driven..........	7,500	lbs.
Field rivets when power driven.	9,000	"
Shop rivets and pins..........	10,000	"
Plate girder webs, gross section.	10,000	"
(*e*) *Bearing on:* Turned bolts and field rivets when hand driven.........	15,000	"
Field rivets when power driven.	18,000	"
Shop rivets and pins.........	20,000	"

13. Expansion Rollers.
Allowable pressure per lin. in................... 600d
where d = diameter of roller in inches.

14. Combined Stresses. When the effect of bending stresses due to wind loading is considered and added to the axial and bending stresses, due to other causes, the above unit stresses (Par. 12) may be increased 25 per cent.

15. Eccentric Stresses. Provision must be made for eccentric loading on columns and other members. Whenever angles used as web members or bracing are connected up by one leg only, the above unit stresses (Par. 12) shall be decreased 25 per cent.

16. Reversal of Stresses. Members and connections subject to reversal of stresses shall be proportioned for an equivalent stress equal to that stress which, when added to 50 per cent of the other, will give the greater section.

17. Cast Iron. The maximum stresses shall not exceed, *in pounds per square inch*, for

Tension	2,500	lbs.
Compression (on blocks)	12,000	"
Shear	1,500	"

UNIT STRESSES: MASONRY, FOUNDATIONS

18. Pressure on Walls. The pressure on walls caused by beams, girders, wall plates, etc., shall not exceed the following values *in pounds per square inch.*

On brickwork, laid in lime mortar	150	lbs.
" " cement mortar	200	"
On terra-cotta, hollow	75	"
" solid	150	"
On cinder concrete 1:2:6	125	"
On Portland cement concrete 1:2½:5	275	"
" " 1:2 :4	350	"
On ordinary rubble masonry, cement mortar	150	"
On first-class stone masonry, cement mortar	400–600	"

19. Pressure on Foundations. The pressure on masonry or foundations caused by column bases, etc., shall not exceed the following values *in pounds per square inch:*

Dimension stones	125	lbs.
Portland cement concrete 1:2½:5	300	"
" " 1:2 :4	400	"
" " 1:2:0 (granitoid)	600	"

Other values as given above (Pars. 17, 18).

20. Pressure on Soils. The pressure on soils caused by foundations, walls, etc., shall not exceed the following values in *tons per square foot:*

Earth, ordinary	$1\frac{1}{2}$	tons
" tamped or naturally solid	3	"
Clay, soft	1	"
" dry or mixed with dry sand	2	"
" hard pan	3	"
" hard and mixed with coarse sand	4	"
Sand and gravel mixed, when dry and coarse	6	"
Rock, broken or partly disintegrated	5–25	"
Rock, solid bed	200	"

21. Bearing Power of Piles. Wooden piles shall be spaced not less than 30 in. c. to c.

When the piles are driven through wet and loose soil to a good bearing the pressure shall not exceed 300 lbs. per sq. in. of their average cross-section. When driven through a firm soil this pressure may be increased to 600 lbs. (Pars. 270, 277.)

Design of Framing

22. Roof Trusses. Roof trusses shall preferably be of such type as will allow the purlins to be placed only at the panel points. Wherever this is neither practicable nor economical, the top chord shall be designed for both bending and direct stresses.

Roof trusses shall be riveted throughout, except in special cases for long spans where the field splices and main joints may be pin-connected.

23. Spacing of Roof Trusses. The spacing of roof trusses shall preferably be such as to allow only the use of single rolled shapes as purlins (Par. 26). Whenever this limit be exceeded intermediate jack-rafters may be used. For ordinary roofs the most economical spacing of trusses will generally be as follows:

For spans up to	40	ft.	16′ 0″	c. to c.
" " from	40–55	"	17′ 0″	"
" " "	55–70	"	18′ 0″	"
" " "	70–85	"	19′ 0″	"
" " "	85–100	"	20′ 0″	"

24. Pitch of Roofs. The pitch must vary according to circumstances, but shall preferably be made as follows:

For tar and gravel roofs.........from $\frac{1}{32}$ to $\frac{1}{24}$
" tile, corrugated steel and
shingled roofs.......... " $\frac{1}{5}$ to $\frac{1}{3}$
" slate roofs................. " $\frac{1}{4}$ and up

25. Bracing. Roof trusses shall be braced in pairs; in the plane of the top chord the bracing may be made adjustable, whereas in the plane of the bottom chord the bracing must be rigid.

Bracing in planes of the sides and ends of buildings may also be made adjustable.

Knee-braces must be provided wherever practicable, for instance, between trusses and columns and between crane girders and columns.

26. Purlins. Both steel and timber purlins shall be attached to the roof trusses by means of lug angles. Steel purlins shall be composed of single-rolled shapes (Z-bars, [s, I-beams and Ls) whenever possible, and be of a depth $\geqq$ than one-thirtieth ($\frac{1}{30}$) of the span. Otherwise plate girder or lattice girder purlins shall be used, and no trussed purlins will be permitted.

Purlins shall generally be spaced from 4 ft. to 5 ft. apart for all forms of roof covering except reinforced concrete, where the spacing may be increased to 12 ft.

27. Girts. Girts shall be attached to columns by means of lug angles and shall be composed of single rolled shapes. They shall generally not be spaced more than 4 ft. apart.

28. Beam Girders. Beams composed of single rolled shapes (I-beams and [s) shall be proportioned by their moment of inertia.

No beam shall be used whose flange width is less than one-twentieth ($\frac{1}{20}$) of the span length, unless its compression flange is properly supported sidewise against buckling. When more than one beam is used to form a girder, they shall be connected by bolts and separators, so as to bring the unsupported flange width within the above ratio, spaced with a maximum limit of 5 ft. Beams used in floors shall have a depth of not less than one-twentieth ($\frac{1}{20}$) of the span length; they shall be riveted

to the columns, whenever such occur, by means of connection angles which must carry the entire load. Shelf angles may be provided for convenience during the erection. The free end of such floor beams must be securely anchored to the walls.

29. **Plate Girders** (see Part IV).

Details of Design

30. **Minimum Size of Material.** No rolled shape or metal of less thickness than $\frac{1}{4}$ in. shall be used except for fillers. No angles shall be less than $2\frac{1}{2}'' \times 2'' \times \frac{1}{4}''$ and no rivets, except in beam connections and lacing bars, shall be less than $\frac{3}{4}$ in. in diam. (Pars. 33, 38, 45, 46.)

31. **Details of Joints.** Main members of trusses shall be so arranged around the joints that their neutral axes will meet in a common point.

All joints in riveted work, whether in tension or in compression, shall be fully spliced.

32. **Details of Connections.** The strength of connections shall be such as to cause the main member to fail should the combination be tested to destruction. No connection, except for lattice bars, shall have less than two rivets.

33. **Rivets.** In main members composed of angles the maximum diameter of rivet used shall not exceed one-quarter ($\frac{1}{4}$) the width of leg through which it passes. Three-quarter ($\frac{3}{4}$) in. rivets shall not be countersunk in plates less than $\frac{3}{8}$ in. in thickness and $\frac{7}{8}$-in. rivets shall not be countersunk in plates less than $\frac{7}{16}$ in. in thickness.

Except in bed plates, no rivet shall be of less diameter than the thickness of the thickest plate through which it passes.

34. **Rivet Spacing.** The minimum pitch shall never be less than three diameters of the rivet and, if possible, not less than $3''$ for $\frac{7}{8}''$ rivets, $2\frac{1}{2}''$ for $\frac{3}{4}''$ rivets, $2\frac{1}{4}''$ for $\frac{5}{8}''$ rivets, and $1\frac{3}{4}''$ for $\frac{1}{2}''$ rivets.

The maximum pitch of rivets, in the direction of the stress, shall not exceed 6 in., or 16 times the thinnest outside plate connected, and not more than 40 times that thickness at right angles to the stress, except when two or more plates in contact are to be held together, where the pitch may be 12 in. in any direction.

The maximum pitch at ends of built up compression mem-

bers shall not exceed four diameters of the rivet for a length equal to two times the width of the member.

35. Edge Distance of Rivets. The minimum distance from the center of any rivet hole to a sheared edge shall be 1½" for ⅞" rivets, 1¼" for ¾" rivets, 1⅛" for ⅝" rivets, and 1" for ½" rivets, and to a rolled edge, except in flanges of I-beams and channels, 1¼", 1⅛", 1" and ⅞" respectively. The maximum distance from any edge shall be eight (8) times the thickness of the outside plate, but shall not exceed 5 in.

36. Tension Members. In calculating the net area of tension members the area of rivet holes must be deducted, assuming the diameter of the hole ⅛ in. larger than the nominal size of the rivet.

Main tension members shall be composed of sections placed symmetrically about the central plane through the truss. Secondary tension members may be made of a single shape. (Par. 15.)

Pin-connected riveted tension members shall have a net section through the pin hole 25 per cent in excess of that through the body of the main member. The minimum net section back of the pin hole, parallel to the axis of the member, shall not be less than that through the body of the main member.

37. Eye-bars. Heads of eye-bars shall be forged and so proportioned as to develop the full strength of the bar. (Par. 43.)

The eye-bars shall be placed in the truss so as to be, as nearly as possible, parallel to its central plane, the maximum inclination being limited to 1 in. in 16 ft.

38. Rods. The minimum size of bracing rods, or laterals, shall be ¾ in. in diameter and they shall be upset at the screw ends. The minimum size of sag rods shall be ⅝ in. in diameter, but these need not be upset.

39. Compression Members. Main compression members shall be composed of sections placed symmetrically about the central plane through the truss. Sub-struts may be made of a single shape. (Par. 15.)

No compression member shall have a length exceeding 120 times its least radius of gyration, except those used for wind and lateral bracing, which may have a maximum length of 140 times their least radius of gyration.

40. Tie-Plates. The open sides of compression members

shall be stayed by diagonal lattice having tie-plates as near each end as practicable and at intermediate points where the lattice is interrupted. In the main members the tie-plates shall have a length of not less than the width of the main member on the connected side, provided that no tie-plate be less than 10 in. long near the ends of such members.

Their minimum thickness shall be one-forty-eighth ($\frac{1}{48}$) of the distance between center lines of the connecting rivets.

41. **Columns.** In proportioning the area of columns the effect of bending stresses due to wind or eccentric loading shall be included.

Columns shall have as few splices as practicable and, where spliced, the splices shall be strong enough to resist the direct as well as the bending stresses.

42. **Lattice Bars.** Single lattice bars shall have an inclination of approximately 60° with the axis of the main member and shall have a minimum thickness of one-fortieth ($\frac{1}{40}$) of the distance between the rivets connecting them to the member.

Single lattice bars may be connected with one rivet, except in flanges more than 5 in. wide, where two rivets shall be used. Lattice angles shall be connected by at least two rivets.

Double lattice bars shall be used where the distance between rivet lines in the flanges exceeds 15 in. They shall have a minimum thickness of one-sixtieth ($\frac{1}{60}$) of the distance between the rivets connecting them to the member, shall have an inclination of approximately 45°, and shall be riveted at their intersection.

The minimum width of lattice bars shall be:

For 15-in. channels, or built sections with angles over 3 in	$2\frac{1}{2}$ in. ($\frac{7}{8}$-in. rivets)
For 12-, 10-, and 9-in. channels, or built sections with 3-in. angles	$2\frac{1}{4}$ in. ($\frac{3}{4}$-in. rivets)
For 8- and 7-in. channels, or built sections with $2\frac{1}{2}$-in. angles	2 -in. ($\frac{5}{8}$-in. rivets)
For 6-in. channels or less	$1\frac{3}{4}$ in. ($\frac{1}{2}$-in. rivets)

43. **Pins.** The minimum diameter of pins shall be eight-tenths ($\frac{8}{10}$) of the width of the widest eye-bar attached to it.

Members shall be packed on pins, using filling rings where necessary, in a manner that will prevent any lateral movement.

44. Pin Holes. Pin holes shall be reinforced by plates where necessary. The plates shall be of such size as to distribute properly, through sufficient rivets, the pin pressure to the webs and their flanges in each segment of the main member.

45. Wall Plates and Column Bases. The minimum thickness shall be ½ in. for wall plates and ¾ in. for base plates. The wall plates and column bases shall be detailed and placed in such a manner that the load will be evenly distributed, using cement mortar or grout for filling if necessary.

They shall be of sufficient size and thickness so as not to exceed the allowable unit stresses. (Pars. 12, 14, 17, 18 and 19.)

46. Anchor Bolts. Columns shall be anchored to the foundations, by means of anchor bolts, when stressed in tension at their base. The minimum diameter of anchor bolts shall be ⅞ in. upset; they shall be of sufficient length to engage a mass of masonry, the weight of which shall be 1½ times the tension.

The anchor bolts shall in all cases be of sufficient size to resist in shear any horizontal force acting thereon.

47. Temperature. Where necessary provision shall be made for expansion and contraction covering a range of 150° F

48. Expansion Rollers. The minimum diameter of expansion rollers shall be 4 in.

PART II

HIGHWAY BRIDGES

General Requirements

49. Classification. Highway bridges may, based upon traffic conditions, be divided into three classes, viz.:

Class A—City bridges, subject to heavy traffic.
Class B—City, Interurban or Country bridges, subject to medium traffic, and
Class C—Country bridges, subject to light traffic.

50. Type of Bridge. The following types of bridges shall preferably be used:

For spans		up to	20 ft., wooden beams or rolled beams.
"	"	from 20 to	40 ft., rolled beams or plate girders.
"	"	" 40 to	70 ft., plate girders.
"	"	" 80 to	100 ft., plate girders or riveted trusses.
"	"	" 100 to	160 ft., riveted trusses.
" long spans, 160 ft. and over, pin-connected trusses.			

Pony trusses shall be avoided wherever possible, but may be used for spans from 40 to 90 ft. (Par. 80.)

51. Materials. All parts of the superstructure, except the flooring and paving, shall be of structural steel, or rivet steel.

Cast iron may be used for minor parts and for ornamental purposes; all other castings shall be of steel.

52. Clearances. All through bridges carrying electric cars shall have a clear head-room, above the top of the rail, of at least 15 ft., for a width of 6 ft. over the center of the track. Where the track is straight there shall be clear width of at least 7 ft. on each side of the center of the track at a height of 12 in. above the top of rails. Where the tracks are curved, the addi-

tional clearance shall be computed by assuming the extreme length of car as 45 ft., width 8 ft., and distance between centers of trucks 20 ft.

Through bridges, not carrying electric cars, shall have a minimum head-room of 14 ft. above roadway, for classes *A* and *B*, and of 12 ft. 6 in. for class *C*, unless otherwise required by local ordinances.

53. **Paved Floors.** Pavements consisting of stone blocks, paving bricks, asphalt, etc., resting upon a bed of concrete, not reinforced, shall be supported upon buckled or corrugated plates. The minimum thickness of this concrete bed shall be 3 in. for the roadway and 2 in. for the sidewalks. Such floors shall be pitched transversely and proper provisions for their thorough drainage shall be made.

Pavements consisting of wooden blocks may rest on a timber floor, consisting of planks laid transversely and at least 4 in. thick.

54. **Wooden Floors.** (See Pars. 271, 279 to 281.)

55. **Cross-Ties.** (See Par. 283.)

56. **Guard-Rails.** (See Par. 284.)

57. **Handrailing.** A handrailing 3 ft. 6 in. high shall be placed on each side of the bridge, except where plate girders serve the same purpose. Where the handrailing is of rolled steel or cast iron it shall be of pleasing design and shall be rigidly attached to the superstructure. For wooden handrailing see Par. 282.

58. **Approaches.** All floor-timbers, rails, guards and handrailings shall extend over all piers and abutments and shall make suitable connection with the embankments at either end of the structure.

Loads

59. **Dead Load.** The dead load consists of:

(*a*) The weight of the steelwork;
(*b*) The weight of the paving, if any;
(*c*) The weight of the wooden flooring, if any, and
(*d*) The weight of the electric railway tracks, if any,

The approximate weight of the steelwork shall be obtained either by trial design or otherwise.

The weight of the paving shall be taken at 160 lbs. per cu.

ft. for stone blocks, at 150 lbs. per cu. ft. for paving bricks, and at 130 lbs. per cu. ft. for concrete and asphalt.

The weight of the wooden flooring shall be taken at $4\frac{1}{2}$ lbs. per foot-board measure for oak, yellow pine and other hard woods, at $3\frac{1}{2}$ lbs. per foot-board measure for white pine and other soft woods.

The minimum weight of cross-ties and guard rails shall be taken at 200 lbs. per lin.ft. of each track, and the weight of rails, fastenings and splices at 100 lbs. per lin.ft. of each track.

60. Live Loads. All bridges shall be designed to carry certain concentrated and certain uniformly distributed loads, as specified below, placed so as to give the greatest stress in each part of the structure.

(*a*) *Class A.* For the floor system and local truss members a concentrated load of 40,000 lbs., distributed on two axles 8 ft. centers and 5 ft. gauge (occupying a length of 20 ft. and a width of 10 ft.), and upon the remaining area of the floor, including sidewalks, a load of 100 lbs. per sq.ft.

For the trusses or girders, 100 lbs. per sq.ft. of entire roadway and sidewalks for spans of 100 ft. or less, 80 lbs. for spans of 200 ft. or over, and proportionally for intermediate spans.

(*b*) *Class B.* For the floor system and local truss members a concentrated load of 30,000 lbs., distributed on two axles 8 ft. centers and 5 ft. gauge (occupying a length of 20 ft. and a width of 10 ft.), and upon the remaining area of the floor, including sidewalks, a load of 90 lbs. per sq.ft.

For the trusses or girders, 90 lbs. per sq.ft. of entire roadway and sidewalks for spans of 100 ft. or less, 70 lbs. for spans of 200 ft. or over and proportionally for intermediate spans.

(*c*) *Class C.* For the floor system and local truss members a concentrated load of 20,000 lbs., distributed on two axles 8 ft. centers and 5 ft. gauge (occupying a length of 20 ft. and a width of 10 ft.), and upon the remaining area of the floor, including sidewalks, a load of 80 lbs. per sq.ft.

For the trusses or girders, 80 lbs per sq.ft. of entire

roadway and sidewalks for spans of 100 ft. or less, 60 lbs. for spans of 200 ft. or over, and proportionally for intermediate spans.

(*d*) *Electric Railways.* Any bridge carrying electric railway tracks (excepting those for exclusive railroad use) shall in addition to one of the above loadings be designed to carry on each track a series of cars, each weighing 100,000 lbs., unless otherwise specified. This load to be distributed equally on two trucks 20 ft. centers, each having two axles 5 ft. centers and 5 ft. gauge (occupying a length of 40 ft. and a width of 10 ft.)

61. Impact. An impact allowance shall be added to the computed maximum live load stresses, as follows:

For bridges of all classes carrying highway traffic only . . . . $\Big\}$ $\text{Impact} = S\left(\frac{100}{L+300}\right)$.

For bridges, or part of bridges, carrying electric railway traffic . . . . $\Big\}$ $\text{Impact} = S\left(\frac{200}{L+300}\right)$,

where S = computed maximum live load stress, moment or shear;
L = loaded length of span in feet.

No impact allowance shall be added to stresses produced by wind, centrifugal or traction forces.

62. Wind Pressure. The wind bracing shall be designed to resist one of the following lateral loadings, whichever produces the greater stress:

(*a*) *Structure unloaded.* 50 lbs. per sq.ft. on the exposed surface of all trusses and the floor as seen in elevation, or

(*b*) *Structure loaded.* (Bridges of all classes carrying highway traffic only), 30 lbs. per sq.ft. on the exposed surface of all trusses and the floor as seen in elevation in addition to a uniform load of 150 lbs. per lin.ft. of structure applied on the "loaded" chord, or

(*c*) *Structure loaded.* (Bridges of all classes carrying electric railway traffic) the same loading as under (*b*), except that the additional uniform load is 300 lbs. per lin.ft. of structure and is applied 7 ft. above the base of rail.

The minimum value of the above pressures shall be 250 lbs. per lin.ft. for the "loaded" and 150 lbs. for the "unloaded" chord of the structure.

Trestles shall in addition to one of the above wind loadings be designed to resist a pressure of 200 lbs. for each vertical foot of bent in height.

The above wind pressure shall in all cases be treated as moving loads. (Par. 61.)

63. Centrifugal Force. Any structure on a curve carrying an electric railway shall be designed to resist a lateral force of 10 per cent of the equivalent live load per lin.ft., applied 5 ft. above the top of rail. (Par. 61).

64. Traction Force. Any structure carrying an electric railway shall be designed to resist a longitudinal force of 20 per cent of the greatest live load placed upon the same.

Unit Stresses

65. Structural Steel. In designing the component parts of any highway structure the maximum stresses due to the combined effects from dead and live loads, including impact, or due to wind pressure, centrifugal and traction forces, shall not exceed for structural steel and rivet steel, the following values in lbs. per square inch, except as modified in Pars. 71 to 74.

(*a*) *Axial tension,* net section	16,000 lbs.
(*b*) *Bending,* net section, on extreme fibers of rolled shapes (Par. 77), built sections and plate girders	16,000 "
Joists, under concentrated loads, when flooring is non-continuous (Par. 77)	20,000 "
Pins, on extreme fibers	24,000 "

(*c*) *Axial compression,* gross section,

$$S = 16{,}000 - 70\frac{l}{r}$$

where S = allowable unit stress,

l = unsupported length of member in inches,

r = least radius of gyration of member in inches (Par. 96).

(*d*) *Shear on:* turned bolts and field rivets, when hand driven .... 9,000 lbs.
Field rivets, when power driven............... 11,000 "
Shop driven rivets and pins................ 12,000 "
Plate girder webs, gross section .... 10,000 "
(*e*) *Bearing on:* turned bolts and field rivets, when hand driven .... 18,000 "
Field rivets, when power driven .... 22,000 "
Shop-driven rivets and pins.................. 24,000 "

66. Pressure on Foundations. The pressure on masonry foundations shall not exceed the following values in pounds per square inch:

Portland cement concrete 1 : 2 : 4 and first-class sandstone or limestone masonry, including impact............ 400 lbs.
Portland cement concrete 1 : 2 : 0 (granitoid) and first-class granite masonry, including impact .... 600 "

67. Pressure on Soils. For allowable pressures see Par. 20.

68. Timber. For allowable stresses see Part VII.

69. Expansion Rollers.

Allowable pressure per lin.in 600*d*

where d = diameter of roller in inches.

70. Cast Steel. The maximum stresses shall not exceed, *in lbs. per square inch*, for,

Tension .... 16,000 lbs.
Compression (on blocks) .... 16,000 "
Shear .... 10,000 "

71. Combined Stresses. All members in a structure exposed to bending stresses from a transverse loading, due either to the weight of the member itself, or to the weight of the floor system when it rests directly on one of the chords, shall be designed for the maximum combination of such stresses with the axial stresses, including impact for each kind of loading, using an extreme fiber stress of 16,000 lbs. per sq.in.

Where the bending stresses are due only to the weight of the

member itself and do not exceed 1600 lbs. per sq.in., the effect may be neglected, otherwise the maximum unit stresses (Pars. 65 and 73) may be increased 10 per cent.

The bending moment in chord segments of riveted structures, or in pin-connected members when continuous over joints, shall be computed from the compromise formula,

$$M = \pm 1.2\ wL^2,$$

where M = positive moment at center or negative moment at the joint,

w = total transverse load in lbs. per.lin. ft.,

L = length of member in feet.

72. Eccentric Stresses. Whenever angles, used as web members or bracing, are connected up by one leg only the above unit stresses (Par. 65) shall be decreased 25 per cent.

73. Maximum Stresses. When combining the stresses due to vertical forces with those due to lateral forces, including the direct and indirect wind stresses, centrifugal forces, and bending stresses in the end posts due to wind, the specified unit stresses (Pars. 65 and 71) may be increased 25 per cent, provided that this combination gives a greater sectional area.

74. Reversal of Stresses. Where the stresses due to wind and centrifugal forces reverse the stresses in a member due to vertical forces proper provisions must be made for the piece to resist compression.

Members and connections subject to reversal of stresses shall be proportioned for an equivalent stress equal to that stress which, when added to 50 per cent of the other, will give the greater section, both impacts included.

Design of Structure

75. General Dimensions. The following dimensions shall first be calculated or assumed:

Span of girders, center to center of bearings.

Span of trusses, center to center of pedestals or end pins.

Span of floor-beams, center to center of girders or trusses.

Span of joists or stringers, center to center of floor-beams or one panel length.

Depth of girders, center to center of gravity of chords.
Depth of trusses, center to center of gravity, or center to center of pins, of chords.

76. General Proportions. The width between centers of trusses carrying a single straight electric railway track shall not be less than 15 ft., or for any bridge less than one-twentieth ($\frac{1}{20}$) of the span.

The depth of plate-girder spans shall preferably not be less than one-twelfth ($\frac{1}{12}$) of the span, the depth of lattice girders and pony trusses shall not be less than one-tenth ($\frac{1}{10}$) of the span, and the depth of riveted and pin connected through trusses shall preferably not be less than one-eighth ($\frac{1}{8}$) of the span, or less than the panel length.

77. Floor Framing. Steel joists and stringers shall preferably be riveted to the web of the floor beams. Rolled beams used as joists shall be spaced not to exceed 3 ft. center to center and shall not have a depth of less than one-twentieth ($\frac{1}{20}$) of the span.

If the floor plank be continuous each joist may be assumed to carry only two-thirds ($\frac{2}{3}$) of the concentrated load. The top flanges of stringers must be provided with securely bolted wooden shims for the purpose of spiking the planking thereto.

When end floor beams are not used over the masonry the joists shall have their ends rigidly connected by means of struts and the stringers by means of cross frames.

Floor beams shall preferably be arranged so as to be perpendicular to the girder or truss at the panel points; they may rest upon the top chord in deck bridges, but in through bridges they shall be riveted to the verticals.

Rolled beams used as joints, stringers, or floor beams shall be proportioned by their moment of inertia.

78. Plate Girders. For plate girders used as stringers, floor beams, and main girders, see Part IV.

79. Beam Bridges. When bridges carrying electric railways are built of rolled beams they shall be braced as follows: With a single beam under each rail and for spans under 20 ft. the bracing shall consist of cross channels framed at each end at intervals not exceeding 5 ft., for spans over 20 ft. a cross channel framed at each end with an intermediate diagonal bracing. When two or more beams are placed under each rail the beams shall

be provided with riveted or cast-iron separators spaced not over 5 ft.

80. Pony Bridges. The top chord of pony trusses shall be securely stayed at each panel point by means of gusset plates, knee braces, or wide web members of angles with lattice or web plate when efficiently connected to the floor beams.

81. Deck Bridges. Trusses in deck bridges shall be provided at each panel point in the bottom chord with vertical sway bracing sufficiently strong to carry the lateral forces to which they are subjected.

82. Through Bridges. All trusses shall be so designed that the stresses may be determined with reasonable accuracy; they shall have stiff hip verticals, and in the bottom chord the two end segments shall also be made rigid whenever the stresses reverse or are near that point.

All web members, including counters, except for long spans (Pars. 50, 94, 95), shall be made rigid.

83. Bracing. Ends of all through spans shall be provided with portals of rigid design, which shall be as deep as the required clearance (Par. 52) will allow, and in the end posts proper provision shall be made for the bending stresses produced by such portals.

All the intermediate panel points in the top chord of through spans shall be provided with transverse struts with knee braces or with vertical sway bracing. The struts shall be made of four angles laced and shall have the same depth as the chord, to the upper and lower face of which they shall be riveted by means of connection plates.

In the plane of the "loaded" chord ends of all bridges shall be provided with lateral struts where no end floor beams are used.

Lateral, longitudinal and transverse bracing in all structures shall be composed of rigid members.

84. Steel Trestles. Each trestle bent shall be composed of two columns braced together and, when battered, the batter shall generally not be less than 1 horizontal to 8 vertical or more than 1 horizontal to 4 vertical.

The majority of the bents shall be united in pairs, forming a tower, which shall be rigidly braced on all four sides and shall have four horizontal struts at its base.

The column feet shall be secured to the foundations by means

of details and anchor-bolts capable of resisting one and one-half ($1\frac{1}{2}$) times the specified lateral (Pars. 62, 63) and longitudinal forces. (Pars. 64, 104.)

85. Wooden Trestles. (See Pars. 285, 286, 287.)

86. All Structures. Structures shall be so designed that all parts will be accessible for inspection, cleaning, and painting.

Pockets or depressions which would hold water shall have drain holes, or be filled with waterproof material.

Details of Design

87. Minimum Size of Material. No rolled shape, except channels, or metal of less thickness than $\frac{5}{16}$ in., shall be used except for fillers. The webs of channels shall not be less than $\frac{1}{4}$ in. No angles shall be less than $2\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{5}{16}''$, and no rivets, except in beam connections, lattice and railings, shall be less than $\frac{3}{4}$ in. in diam. (Pars. 95, 101.)

88. Details of Joints. Main members of trusses shall be so arranged around the joints that their neutral axes will meet in a common point.

The sections of top chords and inclined end posts generally consist of two rolled or built-up channels and a cover plate; such unsymmetrical sections must be so proportioned as to bring the neutral axis near the center of the webs. (Par. 90.)

Abutting joints in compression members when faced for bearing shall be spliced on four sides sufficiently to hold the connecting members accurately in place.

All other joints in riveted work, whether in tension or in compression, shall be fully spliced.

89. Details of Connections. The strength of connections shall be such as to cause the main member to fail should the combination be tested to destruction. (Par. 90.)

No connection except for lattice bars or lattice angles shall have less than three rivets.

All joists and stringers shall preferably be attached to the floor beams by means of connecting angles and shall, wherever possible, rest upon shelf angles stiffened by vertical angles if necessary. The rivets, however, in such shelves shall not be assumed to carry any part of the shear.

The calculated number of rivets connecting the stringers

to the floor beams and the floor beams to the trusses shall be increased by 25 per cent.

Where sidewalks are placed outside the trusses, and supported on brackets, the connection shall preferably be made by means of a fully riveted tension plate, as no tension on rivet heads will be allowed.

90. Riveted Work. In riveted work the main members shall be arranged, wherever practicable, so that the effective sectional area is placed symmetrically about the two principal neutral axes. (Par. 88.)

Where two connected members have their centers of gravity in a continuous line the rivets in the splice plates must be arranged symmetrically about these, using the minimum pitch (Par. 34), and, by staggering or otherwise, have as few rivets as possible in planes parallel and perpendicular to the axis of the member.

Where two members are connected by means of gusset plates the rivets must be arranged symetrically about both intersecting center lines of gravity.

The secondary stresses due to non-compliance with these rules must be provided for in the joint by increasing the area of splice or gusset plates and the number of rivets, or both.

91. Rivet Spacing. (See Par. 34.)

92. Edge Distance of Rivets. (See Par. 35.)

93. Tension Members. In calculating the net area of tension members the area of rivet holes must be deducted, assuming the diameter of the hole $\frac{1}{8}$ in. larger than the nominal size of the rivet.

Main tension members shall be composed of sections placed symmetrically about the central plane through the truss. Secondary tension members may be made of a single shape. (Par. 72.)

Pin-connected riveted tension members shall have a net section through the pin hole 25 per cent in excess of that through the body of the main member. The minimum net section back of the pin hole, parallel to the axis of the member, shall not be less than that through the body of the main member.

94. Eye-bars. Heads of eye-bars shall be forged and so proportioned as to develop the full strength of the bar. (Par. 43.)

The eye-bars shall be placed in the truss so as to be, as nearly

as possible, parallel to its central plane, the maximum inclination of any bar being limited to 1 in. in 16 ft.

Adjustable eye-bars, when used as counters, shall have the screw ends upset and shall be provided with turnbuckles, or with sleeve nuts provided with holes drilled through two opposite faces.

95. **Rods.** All rods shall have the loop ends forged and, when used as counters, shall have the screw ends upset and shall be provided with turnbuckles or special sleeve nuts. (Par. 94.) The minimum size of all rods shall be one (1) sq.in.

96. **Compression Members.** In compression members forming chord segments as much as possible of the metal shall be concentrated in the webs and flanges and the neutral axis shall be as near as possible to the center of the web.

In all compression members the minimum thickness of each single web plate shall be one-fortieth ($\frac{1}{40}$) of the distance between the inner lines of rivets connecting it to the flanges, and when two or more plates form a compound web, the minimum thickness of each plate shall be $\frac{7}{16}$ in. (Par. 34.)

The minimum thickness of cover plates shall be one-forty-eighth ($\frac{1}{48}$) of the distance between rivet lines.

The minimum thickness of flange angles, unsupported by cover plates, shall be one-sixteenth ($\frac{1}{16}$) of the width of the unsupported leg.

No compression member shall have a length exceeding 120 times its least radius of gyration, except those used for wind and lateral bracing, which may have a maximum length of 140 times their least radius of gyration.

97. **Tie-Plates.** (See Par. 40.)

98. **Lattice Bars.** (See Par. 42.)

99. **Pins.** (See Par. 43.)

100. **Pin Holes.** (See Par. 44.)

101. **Column Bases in Trestles.** Column bases shall be made of plates and shapes riveted together, and no cast bases or pedestals will be allowed, except when permitted by the engineer. (Par. 84.)

No metal in the bases shall be less than one-half ($\frac{1}{2}$) in. in thickness and the base plates shall not be less than three-quarter ($\frac{3}{4}$) in.

The bases shall be placed on all bearing surfaces and so anchored as to allow for expansion.

102. **Anchor Bolts.** (See Par. 46.)

103. **Camber.** All through truss bridges shall be given a camber by making the panel length of the top chords, or their horizontal projections, longer than the corresponding panels of the bottom chord in the proportion of $\frac{1}{8}$ in. in 10 ft.

104. **Temperature.** Provision shall be made for a free expansion and contraction of all parts, corresponding to a variation of 150° F. in temperature.

For bridges less than 80 ft. in length one end shall be free to move upon smooth surfaces.

Bridges of 80 ft. and over, resting on masonry, shall have hinged bolsters or shoes at both ends, and at one end the shoes shall rest upon a nest of turned expansion rollers, of not less than 4 in. in diameter (Par. 69), moving between planed surfaces. (Par. 86.)

In very high trestle towers one foot shall be fixed, two feet shall be fixed in one direction only, and the fourth shall be free to move in both directions.

PART III

RAILROAD BRIDGES*

General Requirements

105. Material. The material in the superstructure shall be structural steel, except rivets, and as may be otherwise specified.

106. Clearances. On a straight line the clear height of through bridges shall not be less than 21 ft. above the top of rails for a width of 6 ft. over a single track, and the clear width shall not be less than 7 ft. from the center line of the track between the heights of 4 and 17 ft. above the rails.

The width shall be increased to provide the same minimum clearance on curves, for a car 80 ft. long, 14 ft. high, and 60 ft. center to center of trucks, allowance being made both for curvature and superelevation of rail.

107. Cross Ties. (See Par. 283.)

108. Guard Rails. (See Par. 284.)

Loads

109. Dead Load. The dead load shall consist of the estimated weight of the entire suspended structure.

The approximate weight of the steelwork shall be obtained either by trial design or otherwise.

The weight of the ballast shall be taken at 100 lbs. per cu.ft.; the weight of the timber shall be taken at $4\frac{1}{2}$ lbs. per foot-board measure, with a minimum of 250 lbs. per lin.ft. of track, and of rails, fastenings, and splices at 150 lbs. per lin.ft. of track.

110. Live Loads. The live loads, for each track, shall consist of two typical engines followed by a uniform load, according

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* Adapted from General Specifications for Steel Railroad Bridges, 1906, American Railway Engineering and Maintenance of Way Association.

to Cooper's series, or a system of loading giving practically equivalent stresses. The minimum loading shall be Cooper's E.40, as shown in the following diagrams:

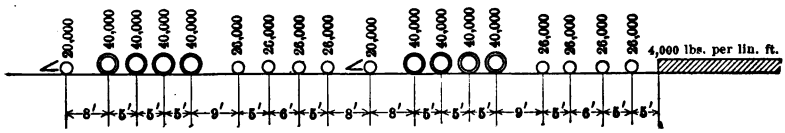

FIG. 1.

or

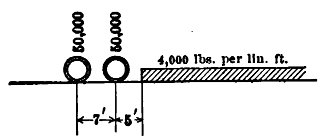

FIG. 2.

The diagram that gives the larger stresses shall be used.

111. Heavier Loading. Heavier loadings shall be proportional to the above diagrams on the same spacing.

112. Impact. An impact allowance shall be added to the computed maximum live load stresses, as follows:

$$\text{Impact} = S\left(\frac{300}{L+300}\right),$$

where S = Computed max. live-load stress, moment or shear.

L = Loaded length of track in feet producing the maximum stress in the member. For bridges carrying more than one track the aggregate length of all tracks producing the stress shall be used.

No impact allowance shall be added to stresses produced by traction, centrifugal and lateral or wind forces.

113. Lateral Force. All spans shall be designed for a lateral force on the "loaded" chord of 200 lbs. per lin.ft. plus 10 per cent of the specified train load on one track, and 200 lbs. per lin.ft. on the "unloaded" chord; these forces being considered as moving.

114. Wind Pressure. Viaduct towers shall be designed for a force of 50 lbs. per sq.ft. on one and one-half ($1\frac{1}{2}$) times the vertical projection of the structure unloaded; or 30 lbs. per sq.ft. on the same surface plus 400 lbs. per lin.ft. of structure applied 7 ft. above the rail for assumed wind load on train when

the structure is either fully loaded or loaded on either track with empty cars, assumed to weigh 1200 lbs. per lin.ft., whichever gives the larger stress.

115. Traction Force. Viaduct towers and similar structures shall be designed for a longitudinal force, applied to the rail, of 20 per cent. of the live load.

116. Centrifugal Force. Any structure located on a curve shall be designed to resist a lateral force of 10 per cent of the equivalent live load per lin.ft., applied 6 ft. above the top of rails. (Par. 112.)

Unit Stresses

117. Structural Steel. All parts of structures shall be so proportioned that the sum of the maximum stresses shall not exceed for structural steel and rivet steel the following values *in lbs. per sq.in.*, except as modified in Paragraphs 122 to 124.

(*a*) *Axial tension,* net section	16,000 lbs.
(*b*) *Bending,* net section, on extreme fibers of rolled shapes, built sections, and plate girders	16,000 "
Pins, on extreme fibers	24,000 "

(*c*) *Axial compression,* gross section,

$$S = 16000 - 70\frac{l}{r}$$

where S = allowable unit stress,
l = unsupported length of member in inches,
r = Least radius of gyration of member in inches. (Par. 143.)

(*d*) *Shear on:* Turned bolts and field rivets, when hand driven	9,000 lbs.
Field rivets, when power driven	11,000 "
Shop-driven rivets and pins	12,000 "
Plate girder webs, gross section	10,000 "
(*e*) *Bearing on:* Turned bolts and field rivets, when hand driven	18,000 "
Field rivets, when power driven	22,000 "
Shop-driven rivets and pins	24,000 "
Expansion rollers, per lin.in.	600*d*

where d = Diameter of roller in inches.

118. Pressure on Foundations. The pressure on masonry foundations shall not exceed the following values *in lbs. per square inch:*

Portland cement concrete 1:2:4 and first-class sandstone or limestone masonry, including impact.	400 lbs.
Portland cement concrete 1:2:0 (granitoid) and first-class granite masonry, including impact	600 "

119. Pressure on Soils. For allowable pressures see Par. 20.

120. Timber. For allowable stresses see Part VII.

121. Cast Steel. For allowable stresses see Par. 70.

122. Alternate Stresses. Members subject to alternate stresses of tension and compression shall be proportioned for the stress giving the largest section.

If alternate stresses occur in succession during the passage of one train, as in stiff counters, each stress shall be increased by 50 per cent of the smaller. The connections shall in all cases be proportioned for the sum of the stresses.

123. Counter-Stresses. Wherever the live- and dead-load stresses are of opposite character, only 70 per cent of the dead-load stress shall be considered as effective in counteracting the live-load stress.

124. Combined Stresses. Members subject to both axial and bending stresses shall be proportioned so that the combined fiber stresses will not exceed the specified axial stresses. (Par. 117.)

For stresses produced by longitudinal and lateral or wind forces combined with those from live and dead load and centrifugal forces, the specified unit stresses (Par. 117) may be increased 25 per cent, provided that this combination gives a greater sectional area.

Design of Structure.

125. General Proportions. The width between centers of trusses shall in no case be less than one-twentieth ($\frac{1}{20}$) of the span, nor less than is necessary to prevent overturning under the assumed lateral loading.

Trusses shall preferably have a depth of not less than one-

tenth ($\frac{1}{10}$) of the span. Plate girders and rolled beams, used as girders, shall preferably have a depth of not less than one-twelfth ($\frac{1}{12}$) of the span. If shallower trusses, girders, or beams be used the section shall be increased so that the maximum deflection will not be greater than if the above limiting ratios had not been exceeded.

For general dimensions see Par. 75.

126. Floor Framing. Stringers shall preferably be riveted to the webs of all intermediate floor beams by means of connection angles not less than $\frac{7}{16}$ in. thick. Shelf angles, or other means provided to support the stringers during erection, shall not be considered as carrying any of the reaction.

Floor beams shall preferably be arranged so as to be perpendicular to the girder or truss at the panel point, they may rest upon the top chord in deck bridges, but in through bridges they shall be riveted to the verticals.

Where end floor beams are not used stringers resting on masonry shall have cross frames near their ends. These frames shall be riveted to girder or truss shoes where practicable. (Par. 129.)

127. Beam and Plate-Girder Bridges. (See Pars. 79, 125, and Part IV.)

128. Pony Bridges. Pony trusses shall be riveted structures with double-webbed chords and shall have all web members latticed or otherwise effectively stiffened. (Par. 80.)

129. Deck Bridges. Deck spans shall have transverse bracing at each end proportioned to carry the lateral load to the supports. (Par. 81.)

130. Through Bridges. All trusses shall be so designed that the stresses may be determined with reasonable accuracy.

The hip verticals and similar members, and the two end panels of the bottom chords of all single-track pin-connected trusses, and of all double-track trusses over 300 ft. span, shall be made rigid.

Rigid counters are preferred, and where subject to reversal of stress shall preferably have riveted connections to the chords. Adjustable counters shall have open turnbuckles.

131. Bracing. Lateral, longitudinal, and transverse bracing in all structures shall be composed of rigid members.

Through truss spans shall have riveted portals which shall be

rigidily connected to the end posts and the top chords. They shall be as deep as the clearance will permit.

Intermediate transverse frames shall be used at each panel of through spans having vertical truss members where the clearance will permit.

Lateral bracing shall be far enough below the flange to clear the ties.

The minimum-sized angle to be used in lateral bracing shall be $3\frac{1}{2}'' \times 3'' \times \frac{3}{8}''$. Not less than three rivets through the end of the angles shall be used at the connection.

132. Steel Trestles. The struts at the foot of trestle towers shall be strong enough to slide the movable shoes when the track is unloaded. (Par. 84.)

133. All Structures. Structures shall be so designed that all parts will be accessible for inspection, cleaning, and painting.

Pockets or depressions which would hold water shall have drain holes, or be filled with waterproof material.

Details of Design

134. Minimum Size of Material. The minimum thickness of metal, except for fillers, shall be $\frac{3}{8}$ in.

Flanges of girders or built members without cover plate shall have a minimum thickness of one-twelfth ($\frac{1}{12}$) of the width of the outstanding leg. (Par. 131.)

135. Details of Joints. Main members of trusses shall be so arranged around the joints that their neutral axes will be as nearly as practicable in the center of the section and the neutral axes of intersecting main members shall meet in a common point.

Abutting joints in compression members when faced for bearing shall be spliced on four sides sufficiently to hold the connecting members accurately in place.

All other joints in riveted work, whether in tension or in compression, shall be fully spliced.

Where splice plates are not in direct contact with the parts which they connect rivets shall be used on each side of the joint in excess of the number theoretically required to the extent of one-third ($\frac{1}{3}$) of the number for each intervening plate.

136. Details of Connections. The strength of connections shall be sufficient to develop the full strength of the member,

even though the computed stress is less, the kind of stress to which the member is subjected being considered.

137. Riveted Work. (See Par. 90.)

138. Rivets. In proportioning rivets their nominal diameter shall be used. Rivets shall generally be $\frac{7}{8}$ in. in diameter, and no rivets, except in lattice bars, shall be less than $\frac{3}{4}$ in. in diameter.

The diameter of the rivets in any angle carrying a calculated stress shall not exceed one-quarter ($\frac{1}{4}$) the width of the leg through which they are driven. In minor parts $\frac{7}{8}$-in. rivets may be used in 3-in. angles and $\frac{3}{4}$-in. rivets in $2\frac{1}{2}$-in. angles.

Rivets carrying a calculated stress and whose grip exceeds four diameters shall be increased in number, at least 1 per cent for each additional $\frac{1}{16}$ in. of grip.

Rivets carrying stress and passing through fillers shall be increased 50 per cent in number, and the excess rivets, when possible, shall be outside the connected member.

Rivets connecting flanges and lattice bars shall have sizes as follows: $\frac{7}{8}$-in. rivets in flanges $3\frac{1}{2}$ in. wide and over, $\frac{3}{4}$-in. rivets in flanges from $2\frac{1}{2}$ to $3\frac{1}{2}$ in., and $\frac{5}{8}$-in. rivets in flanges less than $2\frac{1}{2}$ in. wide.

139. Rivet Spacing. The minimum distance between centers of rivet holes shall be three diameters of the rivet and, if possible, not less than 3 in. for $\frac{7}{8}$-in. rivets and $2\frac{1}{2}$ in. for $\frac{3}{4}$-in. rivets. The maximum pitch, in the direction of the stress for members composed of plates and shapes, shall be 6 in. for $\frac{7}{8}$-in. rivets and 5 in. for $\frac{3}{4}$-in. rivets. For angles with two gauge lines and rivets staggered the maximum shall be twice the above in each line.

Where two or more plates are used in contact, rivets not more than 12 in. apart in either direction shall be used to hold the plates together.

In tension members composed of two angles in contact a pitch of 12 in. will be allowed for riveting the angles together.

The maximum pitch at ends of built-up compression members shall not exceed four diameters of the rivet for a length equal to two times the width of the members.

140. Edge Distance of Rivets. The minimum distance from the center of any rivet hole to a sheared edge shall be $1\frac{1}{2}$ in. for $\frac{7}{8}$-in. rivets and $1\frac{1}{4}$ in. for $\frac{3}{4}$-in. rivets, and to a rolled edge

$1\frac{1}{4}$ in. and $1\frac{1}{8}$ in. respectively. The maximum distance from any edge shall be eight (8) times the thickness of the outside plate, but shall not exceed 5 in.

141. Tension Members. In calculating the net area of tension members the area of rivet holes must be deducted, assuming the diameter of the hole to be $\frac{1}{8}$ in. larger than the nominal size of the rivet.

Pin-connected riveted tension members shall have a net section through the pin hole 25 per cent in excess of that through the body of the main member. The minimum net section back of the pin hole, parallel to the axis of the member, shall not be less than that through the body of the main member.

142. Eye-bars. The eye-bars composing a member shall be so arranged that adjacent bars shall not have their surfaces in contact; they shall be, as nearly as possible, parallel to the central plane of the truss, the maximum inclination of any bar being limited to 1 inch in 16 ft.

Adjustable eye-bars, when used as counters, shall have the screw ends upset and shall be provided with turnbuckles, or with sleeve nuts provided with holes drilled through two opposite faces.

143. Compression Members. In compression members forming chord segments as much as possible of the metal shall be concentrated in the webs and flanges and the neutral axis shall be as near as possible to the center of the web.

In all compression members the minimum thickness of each single web plate shall be one-thirty-second ($\frac{1}{32}$) of the distance between the inner lines of rivets connecting it to the flanges and, when two or more plates form a compound web, the minimum thickness of each plate shall be $\frac{7}{16}$ in. (Par. 139.)

The minimum thickness of cover plates shall be one-fortieth ($\frac{1}{40}$) of the distance between rivet lines.

No compression member shall have a length exceeding 100 times its least radius of gyration, except those used for wind and lateral bracing, which may have a maximum length of 120 times their least radius of gyration.

Forked ends on compression members will be permitted only where unavoidable; where used a sufficient number of pin plates shall be provided to make the jaws of twice the sectional area of the main member. At least one of these plates shall extend

to the far edge of the farthest tie-plate and the remainder not less than 6 in. beyond the near edge of the same plate.

144. Tie-plates. The open sides of compression members shall be stayed by diagonal lattice having tie-plates as near each end as practicable and at intermediate points where the lattice is interrupted. In main members the end tie-plates shall have a length not less than the distance between the lines of rivets connecting them to the flanges, and intermediate tie-plates not less than one-half ($\frac{1}{2}$) this distance. Their thickness shall not be less than one-forty-eighth ($\frac{1}{48}$) of the same distance.

145. Lattice Bars. Single lattice bars shall have an inclination of approximately 60 degrees with the axis of the main member and shall have minimum thickness of one-fortieth ($\frac{1}{40}$) of the distance between the rivets connecting them to the member. Single lattice bars may be connected with one rivet, except in flanges more than 5 in. wide, where two rivets shall be used.

Double lattice bars shall be used where the distance between rivet lines in the flanges exceeds 15 in. They shall have a minimum thickness of one-sixtieth ($\frac{1}{60}$) of the distance between the rivets connecting them to the member, shall have an inclination of approximately 45 degrees, and shall be riveted at their intersection.

Lattice bars shall be so spaced that the portion of the flange included between their connection shall be as strong as the member as a whole.

Instead of lattice bars shapes of equivalent strength may be used and where angles are used they shall be connected by at least two rivets.

The minimum width of lattice shall be: $2\frac{1}{2}$ in. for $\frac{7}{8}$ in.-rivets, $2\frac{1}{4}$ in. for $\frac{3}{4}$ in.-rivets and 2 in. for $\frac{5}{8}$ in.-rivets.

146. Pins. The minimum diameter of pins shall be eight-tenths ($\frac{8}{10}$) of the width of the widest eye-bar attached thereto.

Members shall be packed on pins, using filling rings where necessary, in a manner that will prevent any lateral movement.

Pins shall be long enough to insure a full bearing of all the parts connected upon the turned body of the pin. They shall be secured by chamfered nuts or be provided with washers if solid nuts are used. The screw ends shall be long enough to admit of burring the threads.

147. Pin Holes. Pin holes shall be reinforced by plates where necessary, and at least one plate shall be as wide as the flanges will allow and be on the same side as the angles. They shall contain sufficient rivets to distribute their portion of the pin pressure to the full cross-section of the main member.

148. Bolts. Where members are connected by bolts the turned body of these shall be long enough to extend through the metal. A washer at least $\frac{1}{4}$ in. thick shall be used under the nut. Bolts shall not be used in place of rivets except by special permission. Heads and nuts shall be hexagonal.

For anchor bolts see Par. 46.

149. Column Bases in Trestles. (See Par. 101.)

150. Camber. Ordinary truss spans shall be given a camber by making the panel length of the top chords, or their horizontal projections, longer than the corresponding panels of the bottom chord in the proportion of $\frac{1}{8}$ in. in 10 ft. For truss spans of unusual length or loading, draw spans, cantilevers, etc., the camber shall be obtained from the calculated distortion of the various members under their assumed stress.

151. Bearings. Bearing plates may be of cast steel or built up. All bearing plates, built-up pedestals and built-up bolsters or shoes shall be so designed and set upon the masonry that the load will be distributed over the entire bearing area without causing any of the parts to be overstressed.

Movable bearings shall be designed to permit motion in one direction only; fixed bearings shall be firmly anchored to the masonry.

Bridges on inclined grade without pin shoes shall have the sole plates beveled so that the masonry and expansion surfaces may be level.

152. Temperature. Provision shall be made for a free expansion and contraction of all bridge structures to the extent of $\frac{1}{8}$ inch for each 10 ft. in length. Efficient means shall be provided to prevent excessive motion at any one point.

For bridges less than 80 ft. in length one end shall be free to move upon smooth surfaces.

Bridges of 80 ft. and over, resting on masonry, shall have hinged bolsters or shoes at both ends. At one end the shoes shall rest upon a nest of turned expansion rollers, or rockers may be used for the same purpose.

Expansion rollers shall not be less than 4 in. in diameter. (Par. 117*e*.) They shall be coupled together with substantial side bars which shall be so arranged that the rollers can be readily cleaned. (Par. 133.)

In very high trestle towers one foot shall be fixed, two feet shall be fixed in one direction only, and the fourth shall be free to move in both directions.

PART IV

PLATE GIRDERS

153. General Requirements. (See Pars. 49–58 and 105–108.)

154. Loading. The loading upon plate girders shall be taken, when used in

Buildings, from Pars. 1, 2 and 8–11;
Highway bridges, from Pars. 59–64; and
Railroad bridges, from Pars. 109–116.

155. Unit Stresses. All parts of plate girders, or plate-girder bridges, shall be so proportioned that the sum of the maximum stresses shall not exceed for structural steel and rivet steel the following values *in pounds per square inch,* except as modified in Par. 124.

(*a*) *Axial tension,* net section	16,000 lbs.
(*b*) *Bending,* net section of tension flange (Par. 163)	16,000 "
Pins, on extreme fibers	24,000 "

(*c*) *Axial compression,* gross section,

$$S = 16{,}000 - 70\frac{l}{r},$$

where S = allowable unit stress,
l = unsupported length of member in inches (Par. 167),
r = least radius of gyration of member in inches. (Pars. 39, 96 and 143.)

(*d*) *Shear on:* Turned bolts and field rivets, when hand driven	9,000 lbs.
Field rivets, when power driven	11,000 "
Shop-driven rivets and pins	12,000 "
Webs of girder, gross section	10,000 "

(*e*) *Bearing on:* Turned bolts and field rivets when hand driven. . . . . 18,000 "
Field rivets when power driven. . . . . 22,000 "
Shop-driven rivets and pins. . . . . 24,000 "
Expansion rollers, per lin. inch. . . . . $600d$

where d = diameter of roller in inches.

(*f*) For *girders in buildings* the above unit stresses for rivets and pins shall be reduced $16\frac{2}{3}$ per cent.

(*g*) For combined stresses see Par. 124.
For allowable unit stresses in cast steel see Par. 70.
For allowable pressures on walls and masonry foundations see Pars. 18 and 66.
For allowable pressures on soils see Par. 20.

156. General Proportions. The width between centers of girders in deck bridges, carrying a single straight electric railway or railroad track, shall generally be as follows:

For spans		up to 60 feet inclusive		6′ 6″
" "	from 60 feet to 80	"	"	7′ 0″
" "	" 80 "	and over		7′ 6″

In through bridges the girders shall generally be spaced so as to give a clear width of 10 ft. at the top of rails increasing to 14 ft. at a height of 4 ft. above same.

For additional clearance on curves see Pars. 52 and 106.

The depth of plate girders in buildings shall preferably not be less than one-sixteenth ($\frac{1}{16}$) of the span, or in bridges less than one twelfth ($\frac{1}{12}$) of the span and, if shallower girders be used, the section be increased so that the deflection will not be greater than if the above limiting ratios had not been exceeded.

For general dimensions see Par. 75.

157. Through Bridges. Through plate girders shall have their top flanges stayed at each end of every floor beam, or in case of solid floors, at distances not exceeding 12 ft., by knee braces or gusset plates stiffened by angles.

Where flooring or ties are supported on shelf angles riveted to the webs of the girders these angles shall have a minimum

thickness of $\frac{3}{8}$ in. and shall have their outstanding leg not over $3\frac{1}{2}$ in., unless they are supported by stiffeners at intervals not over 30 in. Such shelf angles shall not be considered as a part of the flange.

Through plate girders shall preferably have their upper corners neatly rounded off to a radius not exceeding 3 ft., or less than one-third ($\frac{1}{3}$) of the depth of the girder.

Where the bridge is composed of two or more spans only the corners at the extreme ends need be rounded, unless the girders vary in depth, in which case the deeper ones shall have their top flanges rounded to meet the corner of the adjacent girder. (Par. 163.)

158. **Skew Bridges.** Ends of deck-plate girders, and in through bridges ends of track stringers at abutments, shall be square to the track, unless a ballasted floor be used.

159. **Design of Girder.** Plate girders shall be designed either by the moment of inertia of their net section, or by assuming that the flange areas are concentrated at their centers of gravity, in which case one-eighth ($\frac{1}{8}$) of the gross section of the web, if properly spliced, may be used as flange section.

160. **Design of Flanges.** In girders having flange plates the total flange area shall be so divided that forty per cent (40%) or more will be concentrated in the flange angles and side plates, if any, and the remainder in the cover plates.

Where two or more cover plates are used they shall be of equal thickness, or shall decrease in thickness outward from the angles.

161. **Flange Plates.** The flange plates of all girders shall be limited in width, so as not to extend beyond the outer lines of rivets connecting them to the angles more than 8 times the thickness of the outside plate, or more than 5 in. (Par. 171.)

All cover plates shall extend at each end at least 12 in. beyond the points where they might be cut off theoretically.

162. **Flange Splices.** Flange splices, where unavoidable, shall be located at points where there is a considerable excess of sectional area. Flange angles and flange plates shall all break joints so that no two pieces will be spliced within 18 in. of each other. In general no field splices will be allowed in girders less than 70 feet long; this provision, however, does not apply to work intended for export. (Par. 135.)

163. Compression Flange. The gross section of the compression flange shall not be less than the gross section of the tension flange. The unsupported length of the flange shall generally not exceed 16 times its width in buildings, or 12 times its width in bridges.

Where the unsupported length exceeds these ratios the flange shall be considered as a column between the points of support.

The compression flanges of girders without cover plates shall, in buildings, have a minimum thickness of one-sixteenth ($\frac{1}{16}$) of the width of the outstanding leg, and in bridges a minimum thickness of one-twelfth ($\frac{1}{12}$).

In bridges, where cover plates are used, one plate of the top flange shall extend the whole length of the girder. In through bridges this plate, or a plate of the same width, shall be extended over the rounded corners and be continued down, either below the corners of the adjacent girders, or at the extreme ends of the bridges down to the bottom of the girder. (Par. 157.)

164. Flange Rivets. The flanges of plate girders shall be connected to the web with a sufficient number of rivets to transfer the calculated shear at any point, in a distance equal to the distance between centers of gravity of rivet lines at that point, combined with any load that is applied directly on the flange.

The wheel loads, where rails rest directly on the flange, shall be assumed to be distributed over 30 in.; where the ties rest on the flanges the wheel loads shall be assumed to be distributed over three ties. (Pars. 171, 283.)

165. Design of Web. The web shall be designed for the total maximum shear, assuming this to be uniformly distributed over its gross area.

166. Web Splices. When necessary to splice the web the splice plates and the number of rivets shall be sufficient to resist the maximum stresses resulting from a combination of bending and shear at that point. (Par. 171.)

167. Web Stiffeners. Web stiffeners shall be located in pairs at the ends and inner edges of bearings and at points of concentrated loads, their area to be determined by the formula:

$$S = 16{,}000 - 70\,\frac{l}{r},$$

where S = allowable unit stress.

l = one-half the depth of girder in inches.

r = Radius of gyration of angles, neglecting fillers and inclosed portion of web.

End stiffeners, those under concentrated loads and at web splices, shall be on fillers and have their outstanding legs as wide as the flange angles will allow and shall fit tightly against them.

Where the thickness of the web is less than one-sixty-fourth ($\frac{1}{64}$) of its depth between inner rivet lines intermediate stiffeners shall be used.

The intermediate stiffeners shall be spaced by the formula:

$$\text{For girders in buildings } d \overline{\gtrless} 64t\left(\frac{16000}{Q}\right).$$

$$\text{For girders in bridges } d \overline{\gtrless} 64t\left(\frac{12000}{Q}\right);$$

where d = distance in inches between centers of stiffeners, with a maximum distance equal to the depth of the girder, or 64 in.

t = thickness of web in inches;

Q = shear in web per square inch.

Intermediate stiffeners may be offset (crimped), and their outstanding legs shall not be less than one-thirty-second ($\frac{1}{32}$) of the depth of the girder plus 2 in.

168. Bracing. All deck-plate girder bridges shall have lateral bracing near the plane of the top chord, but far enough below the flanges to clear the ties, and those having a span of 60 ft. or over shall in addition have lateral bracing in the plane of the bottom chord. Cross frames shall be located near each end and at intermediate points not exceeding 20 ft. The lateral system shall generally be of the single cancellation type.

Through-plate girder spans, not having a solid floor, shall have a single system of stringer bracing and a lateral, double-intersection system of bracing in the plane of the bottom chord. All bracing shall be composed of rigid members. (Par 131.)

169. Minimum Size of Material. The minimum thickness of metal, except for fillers, shall be for girders in building or

highway bridges $\frac{5}{16}$ in. with $\frac{3}{4}$-in. rivets, and for girders in railroad bridges $\frac{3}{8}$ in. with $\frac{7}{8}$-in. rivets.

170. **Rivets.** In proportioning rivets their nominal diameter shall be used. The diameter of the rivets in any angle carrying a calculated stress shall not exceed one-quarter ($\frac{1}{4}$) the width of the leg through which they are driven. Rivets carrying a calculated stress and whose grip exceeds four diameters shall be increased in number, at least one per cent for each additional $\frac{1}{16}$ in. of grip.

171. **Rivet Spacing.** The minimum distance between centers of rivet holes shall be three diameters of the rivet and, if possible, not less than 3 in. for $\frac{7}{8}$-in. rivets and $2\frac{1}{2}$ in. for $\frac{3}{4}$-in. rivets. In the flanges the maximum pitch, in the direction of the stress, shall be 6 in. for $\frac{7}{8}$-in. rivets and 5 in. for $\frac{3}{4}$-in. rivets. For angles with two gauge lines and rivets staggered the maximum shall be twice the above in each line. Cover plates more than 16 in. wide shall have four lines of rivets. (Pars. 161 and 164.)

The maximum pitch at ends of cover plates shall not exceed four diameters of the rivet for a length equal to two times the width of the plate.

The maximum pich in stiffeners shall be determined by the loading, if any, but shall in no case exceed $4\frac{1}{2}$ in. The vertical web splice shall, where no horizontal plates are used, have at least two rows of rivets on each side of the joint with the above maximum pitch.

172. **Edge Distance.** (See Par. 140.)

173. **Bearings.** (See Par. 151.)

174. **Temperature.** (See Par. 152.)

PART V

MATERIALS AND WORKMANSHIP

Materials for Structural and Rivet Steel

175. **Process of Manufacture.** Steel shall be manufactured by the open-hearth process.

176. **Schedule of Requirements.** The chemical and physical properties shall conform to the following limits, except as modified in Pars. 177 to 180. The yield point, as indicated by the drop of beam, shall be recorded in the test reports.

Elements Considered.	Structural Steel.	Rivet Steel.	Cast Steel.
Phosphorus, max. Basic	0.04%	0.04%	0.05%
Phosphorus, max. Acid..	0.06%	0.04%	0.08%
Sulphur, maximum........	0.05%	0.04%	0.05%
Ultimate tensile strength in pounds per square inch*................	Desired 60,000	Desired 50,000	Not less than 65,000
Elongation, min. % in 8 in., Fig. 3............	$\frac{1{,}500{,}000†}{\text{Ult. tensile strength}}$	$\frac{1{,}500{,}000}{\text{Ult. tensile strength}}$	15%
Elongation, min. in 2 in., Fig. 4..................	22%		
Character of fracture.......	silky	silky	silky or fine granular.
Cold bends without fracture..................	180° flat‡	180° flat§	in 90°, $d=3$

177.* **Allowable Variations.** If the ultimate strength varies more than 4000 lbs. from that desired a retest shall be made on the same gauge, which, to be acceptable, shall be within 5000 lbs. of the desired ultimate.

178.† **Modification in Elongation.** For material less than $\frac{5}{16}$ in. and more than $\frac{3}{4}$ in. in thickness the following modifications will be allowed in the requirements for elongation:

(*a*) For each $\frac{1}{16}$ inch in thickness below $\frac{5}{16}$ in. a deduction of $2\frac{1}{2}$ will be allowed from the specified percentage.

(*b*) For each $\frac{1}{8}$ in. in thickness above $\frac{3}{4}$ in. a deduction of 1 will be allowed from the specified percentage.

179.‡ Bending Tests. Bending tests may be made by pressure or by blows. Plates, shapes, and bars less than 1 in. thick shall bend as called for in Par. 176.

Full-sized material for eye-bars and other steel 1 in. thick and over, tested as rolled, shall bend cold 180 degrees around a pin, the diameter of which is equal to twice the thickness of the bar, without any fracture on the outside of bend.

Angles $\frac{3}{4}$ in. and less in thickness shall open flat, and angles $\frac{1}{2}$ in. and less in thickness shall bend shut, when cold, under blows of a hammer, without sign of fracture. This test will be made only when required by the inspector.

180.§ Nicked Bends. Rivet steel, when nicked and bent around a bar of the same diameter of the rivet rod, shall give a gradual break and a fine, silky, uniform fracture.

181. Chemical Analyses. Chemical determinations of the percentages of carbon, phosphorus, sulphur and manganese shall be made by the manufacturer from a test ingot taken at the time of the pouring of each melt of steel and a correct copy of such analysis shall be furnished to the Engineer or his inspector. Check analyses shall be made from finished material, if called for by the purchaser, in which case an excess of 25 per cent. above the required limits will be allowed.

182. Form of Specimens.

(*a*) *Plates, Shapes and Bars*: Specimens for tensile and bending tests for plates, shapes and bars shall be made

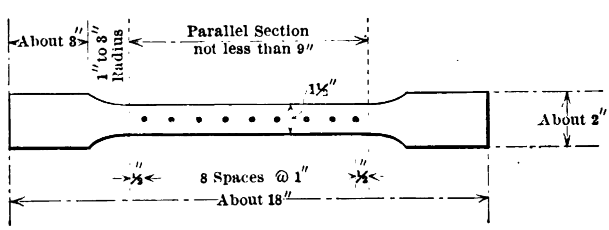

FIG. 3.

by cutting coupons from the finished product, which

shall have both faces rolled and both edges milled to the form shown by Fig. 3; or with both edges parallel; or they may be turned to a diameter of $\frac{3}{4}$ in. for a length of at least 9 in. with enlarged ends.

(*b*) *Rivets*: Rivet rods shall be tested as rolled.

(*c*) *Pins and Rollers*: Specimens shall be cut from the finished rolled or forged bar, in such a manner that the center of the specimen shall be 1 in. from the surface of the bar. The specimen for tensile test shall be turned to

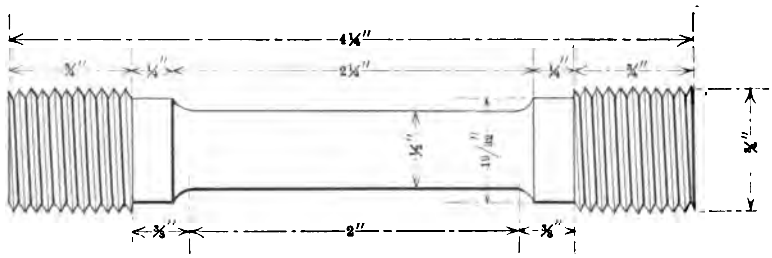

FIG. 4.

the form shown in Fig. 4. The specimen for bending test shall be 1 in. by $\frac{1}{2}$ in. in section.

(*d*) *Cast Steel*. The number of tests will depend on the character and importance of the castings. Specimen shall be cut cold from cupons molded and cast on some portion of one or more castings from each melt or from the sink heads, if the heads are of sufficient size. The coupon or sink head, so used, shall be annealed with the casting before it is cut off. Test specimens to be of the form prescribed for pins and rollers.

183. Annealed Specimens. Material which is to be used without annealing or further treatment shall be tested in the condition in which it comes from the rolls. When material is to be annealed, or otherwise treated before use, the specimens for tensile tests representing such material shall be cut from properly annealed or similarly treated short lengths of the full section of the bar.

184. Number of Tests. At least one tensile and one bending test shall be made from each melt of steel as rolled. In case

steel differing $\frac{3}{8}$ in. and more in thickness is rolled from one melt a test shall be made from the thickest and thinnest material rolled.

185. Finish. Finished material shall be free from injurious seams, flaws, cracks, defective edges, or other defects, and have a smooth, uniform, and workmanlike finish. Plates 36 in. in width and under shall have rolled edges.

186. Stamping. Every finished piece of steel shall have the melt number and the name of the manufacturer stamped or rolled upon it. Steel for pins and rollers shall be stamped on the end. Rivet and lattice steel and other small parts may be bundled with the above marks on an attached metal tag.

187. Defective Material. Material which, subsequent to the above tests at the mills, and its acceptance there, develops weak spots, brittleness, cracks or other imperfections, or is found to have injurious defects, will be rejected at the shop and shall be replaced by the manufacturer at his own cost.

188. Allowable Variation in Weight (when ordered to weight). A variation in cross-section or weight of each piece of steel of more than $2\frac{1}{2}$ per cent from that specified will be sufficient cause for rejection, except in case of sheared plates, which will be covered by the following permissible variations applying to single plates only: Plates under $12\frac{1}{2}$ lbs. per sq.ft.

(*a*) Up to 75 in. wide, $2\frac{1}{2}$ per cent above and below the prescribed weight.

(*b*) 75 in. and up to 100 in. wide, 5 per cent above or 3 per cent below.

(*c*) 100 in. wide and over, 10 per cent above or 3 per cent below.

Plates $12\frac{1}{2}$ lbs. per sq.ft. or heavier.

(*d*) Up to 100 in., $2\frac{1}{2}$ per cent above or below.

(*e*) 100 in. wide and over, 5 per cent above or below.

189. Allowable Variation in Weight (when ordered to gauge). Plates will be accepted if they do not measure more than 0.01 in. below the ordered thickness.

An excess over the nominal weight, corresponding to the dimensions on the order, will be allowed for each plate, if not more than that shown in the following table, one cubic inch of rolled steel being assumed to weigh 0.2833 lb.

Thickness Ordered. Inch.	Nominal Weights. Pounds.	Width of Plate.			
		Up to 75″.	75″ and up to 100″.	100″ and up to 115″.	Over 115″.
$\frac{1}{4}$	10.20	10 %	14 %	18 %	
$\frac{5}{16}$	12.75	8 %	12 %	16 %	
$\frac{3}{8}$	15.30	7 %	10 %	13 %	17%
$\frac{7}{16}$	17.85	6 %	8 %	10 %	13%
$\frac{1}{2}$	20.40	5 %	7 %	9 %	12%
$\frac{9}{16}$	22.95	$4\frac{1}{2}$%	$6\frac{1}{2}$%	$8\frac{1}{2}$%	11%
$\frac{5}{8}$	25.50	4 %	6 %	8 %	10%
over $\frac{5}{8}$		$3\frac{1}{2}$%	5 %	$6\frac{1}{2}$%	9%

190. Cast Iron. Except where chilled iron is specified, castings shall be made of tough gray iron, with sulphur not over 0.10 per cent. They shall be true to pattern, out of wind and free from flaws and excessive shrinkage. If tests be demanded they shall be made on the "Arbitration Bar" of the American Society for Testing Materials, which is a round bar $1\frac{1}{4}$ in. in diameter and 15 inches long. The transverse test shall be made on a supported length of 12 in. with a load at middle. The minimum breaking load so applied shall be 2900 lbs. with a deflection of at least $\frac{1}{10}$ in. before rupture.

191. Wrought-Iron Bars. Wrought iron shall be double rolled, tough, fibrous, and uniform in character. It shall be thoroughly welded in rolling and be free from surface defects. When tested in specimens of the form of Fig. 3, or in full-sized pieces of the same length, it shall show an ultimate strength of at least 50,000 lbs. per sq.in., an elongation of at least 18 per cent in 8 inches, with fracture wholly fibrous. Specimens shall bend cold, with the fiber, through 135 degrees, without sign of fracture, around a pin the diameter of which is not over twice the thickness of the piece tested. When nicked and bent, the fracture shall show at least 90 per cent fibrous.

MATERIALS FOR CONCRETE REINFORCEMENT BARS*

192. Process of Manufacture. Steel may be made by either the open-hearth or Bessemer process. Bars shall be rolled from billets.

* As adopted by The Association of American Steel Manufacturers, 1910.

193. Schedule of Requirements. The chemical and physical properties shall conform to the following limits:

Elements Considered.	Structural-Steel Grade.		Hard-Steel Grade.		Cold-twisted Bars.
	Plain Bars.	Deformed Bars.	Plain Bars.	Deformed Bars.	
Phosphorus, max. Bessemer	0.10%	0.10%	0.10%	0.10%	0.10%
Phosphorus, max. Open-hearth	0.06%	0.06%	0.06%	0.06%	0.06%
Ultimate tensile strength, lbs. per sq.in.	55,000 to 70,000	55,000 to 70,000	80,000 mi	80,000 min.	Recorded only
Yield point, minimum, lbs. per sq.in.	33,000	33,000	50,000	50,000	55,000
Elongation, min. per cent in 8 inches	1,400,000 / Ult. tensile strength	1,250,000 / Ult. tensile strength	1,200.000 / Ult. tensile strength	1,000,000 / Ult. tensile strength	5%
Cold bends without fracture:					
Bars under ¾″ in. diam. or thickness	180° $d=t$	180°, $d=t$	180°, $d=3t$	180°, $d=4t$	180°, $d=2t$
Bars ¾″ in. diam. or thickness and over	180°, $d=t$	180°, $d=2t$	90°, $d=3t$	90°, $d=4t$	180°, $d=3t$

The hard-steel grade will be used only when specified.

194. Chemical Determinations. In order to determine if the material conforms to the chemical limitations prescribed in Par. 193, analysis shall be made by the manufacturer from a test ingot taken at the time of the pouring of each melt or blow of steel, and a correct copy of such analysis shall be furnished to the engineer or his inspector.

195. Yield Point. For the purpose of these specifications, the yield point shall be determined by careful observation of the drop of the beam of the testing machine, or by other equally accurate methods.

196. Form of Specimens.

(*a*) Tensile and bending-test specimens may be cut from the bars as rolled, but tensile and bending-test specimens of deformed bars may be planed or turned for a length of at least 9 in. if deemed necessary by the manufacturer in order to obtain uniform cross-section.

(*b*) Tensile and bending-test specimens of cold-twisted bars shall be cut from the bars after twisting, and shall be tested in full size without further treatment, unless otherwise specified as in (*c*), in which case the conditions therein stipulated shall govern.

(*c*) If it is desired that the testing and acceptance for cold-twisted bars be made upon the hot-rolled bars before

being twisted, the hot-rolled bars shall meet the requirements of the structural-steel grade for plain bars shown in this specification.

197. Number of Tests. At least one tensile and one bending test shall be made from each melt of open-hearth steel rolled, and from each blow or lot of ten tons of Bessemer steel rolled. In case bars differing $\frac{3}{8}$ in. and more in diameter or thickness are rolled from one melt or blow, a test shall be made from the thickest and thinnest material rolled. Should either of these test specimens develop flaws, or should the tensile-test specimen break outside of the middle third of its gauged length, it may be discarded and another test specimen substituted therefor. In case a tensile-test specimen does not meet the specifications, an additional test may be made.

The bending test may be made by pressure or by light blows.

198. Modifications in Elongation for Thin and Thick Material. For bars less than $\frac{7}{16}$ in. and more than $\frac{3}{4}$ in. nominal diameter or thickness, the following modifications shall be made in the requirements for elongations:

(*a*) For each increase of $\frac{1}{8}$ in. in diameter or thickness above $\frac{3}{4}$ in., a deduction of one shall be made from the specified percentage of elongation.

(*b*) For each decrease of $\frac{1}{16}$ inch in diameter or thickness below $\frac{7}{16}$ in., a deduction of one shall be made from the specified percentage of elongation.

(*c*) The above modifications in elongation shall not apply to cold-twisted bars.

199. Number of Twists. Cold-twisted bars shall be twisted cold with one complete twist in a length equal to not more than 12 times the thickness of the bar.

200. Finish. Material must be free from injurious seams, flaws, or cracks, and have a workmanlike finish.

201. Variation in Weight. Bars for reinforcement are subject to rejection if the actual weight of any lot varies more than 5 per cent over or under the theoretical weight of that lot.

WORKMANSHIP

202. General. All parts forming a structure shall be built in accordance with approved drawings. The workmanship and finish shall be equal to the best practice in modern bridge works.

203. Straightening Material. Material shall be thoroughly straightened in the shop by methods that will not injure it, before being laid off or worked in any way.

The several pieces forming one built member shall be straight and fit closely together, and finished members shall be free from twists, bends or open joints.

204. Lattice Bars. Lattice bars shall have neatly rounded ends, unless otherwise called for.

205. Finish. Shearing shall be neatly and accurately done and all portions of the work exposed to view neatly finished with sharp cutting tools, a chisel, or a file.

206. Edge Planing. In all material over $\frac{5}{8}$ in. thick the sheared edges or ends shall be planed at least $\frac{1}{8}$ in.

207. Finish of Joints. Abutting joints shall be cut or dressed true and straight and fitted close together, especially where open to view. In compression joints, depending on contact bearing, the surfaces shall be truly faced, so as to have even bearings after they are riveted up complete and when perfectly aligned.

208. Field Connections. Holes for floor beam and stringer connections shall be sub-punched and reamed according to Par. 212 to a steel templet one inch thick.

All other field connections, except those for laterals and sway bracing, shall be assembled in the shop and the unfair holes reamed; and when so reamed the pieces shall be match-marked before being taken apart.

209. Connection Angles. Connection angles for floor beams, stringers, and plate girders shall be flush with each other and correct as to position and length of girder.

When not correct after being riveted up milling will be required and the removal of more than $\frac{1}{16}$ in. from their thickness will be cause for rejection.

210. Rivet Holes. When reaming is not required the diameter of the punch, shall not be more than $\frac{1}{16}$ in. greater than the diameter of the rivet; nor the diameter of the die more than $\frac{1}{8}$ in. greater than the diameter of the punch. (Pars. 212 and 214.)

211. Punching. All punching shall be accurately done. Drifting to enlarge unfair holes will not be allowed. If the holes must be enlarged to admit the rivet, they shall be reamed. Poor matching of holes will be cause for rejection. (Par. 212.)

212. Sub-punching and Reaming. All material more than $\frac{5}{8}$ in. thick shall be sub-punched and reamed or drilled from the solid.

When reaming is required the punch used shall have a diameter not less than $\frac{1}{8}$ in. smaller than the nominal diameter of the rivet. Holes shall then be reamed to a diameter not more than $\frac{1}{16}$ in. larger than the nominal diameter of the rivet. All reaming shall be done with twist drills. (Pars. 208, 213.)

213. Burrs. The outside burrs on reamed holes shall be removed.

214. Reaming after Assembling.* When general reaming is required it shall be done after the pieces forming one built member are assembled and firmly bolted together. If necessary to take the pieces apart for shipping and handling the respective pieces reamed together shall be so marked that they may be reassembled in the same position in the final setting up. No interchange of reamed parts will be allowed.

215. Size of Rivets. The size of rivets, called for on the plans, shall be understood to mean the actual size of the cold rivet before heating.

216. Rivets. Rivets shall be driven by pressure tools wherever possible. Pneumatic hammers shall be used in preference to hand driving.

217. Field Rivets. Field rivets shall be furnished to the amount of 15 per cent plus ten rivets in excess of the nominal number required for each size.

218. Turned Bolts. Wherever bolts are used in place of rivets which transmit shears the holes shall be reamed parallel and the bolts turned to a driving fit. A washer not less than $\frac{1}{4}$ in. thick shall be used under the nut.

219. Riveting. Rivets shall look neat and finished with heads of approved shape, full and of equal size. They shall be central on shank and grip the assembled pieces firmly. Recupping and caulking will not be allowed. Loose, burned, or otherwise defective rivets shall be cut out and replaced. In cutting out rivets great care shall be taken not to injure the adjacent metal. If necessary they shall be drilled out.

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* This paragraph contains a special requirement which, to be valid under these specifications, shall be specifically mentioned in the contract between the purchaser and the manufacturer.

220. Assembling. Riveted, members shall have all parts well pinned up and firmly drawn together with bolts before riveting is commenced. Contact surfaces to be painted. (Par. 250.)

221. Web Plates. In buildings web plates of girders shall not be recessed from the backs of angles more than $\frac{1}{4}$ in.

In bridges web plates of girders which have no cover plates shall be flush with the backs of angles or shall, in the top chord, project above the same not more than $\frac{1}{8}$ in. unless otherwise called for.

When web plates are spliced not more than $\frac{1}{4}$ in. clearance between ends of plates will be allowed.

222. Splice Plates and Fillers. Web splice plates and fillers under stiffeners shall be cut to fit within $\frac{1}{8}$ in. of flange angles.

223. Web Stiffeners. Stiffeners shall fit neatly between flanges of girders. Where tight fits are called for the ends of stiffeners shall be faced and shall be brought to a true contact bearing with the flange angles.

224. Eye-Bars. Eye-bars shall be straight and true to size and shall be free from twists, folds in the neck or head, or any other defect.

Heads shall be made by upsetting, rolling, or forging. Welding will not be allowed. The form of heads will be determined by the dies in use at the works where the eye-bars are made, if satisfactory to the engineer, but the manufacturer shall guarantee the bars to break in the body when tested to rupture. The thickness of head and neck shall not vary more than $\frac{1}{16}$ in. from that specified. (Par. 248.)

225. Boring Eye-Bars. Before boring each eye-bar shall be properly annealed and carefully straightened. Pin holes shall be in the center line of bars and in the center of heads. Bars of the same length shall be bored so accurately that, when placed together, pins $\frac{1}{32}$ in. smaller in diameter than the pin holes can be passed through the holes at both ends of the bars at the same time without forcing.

226. Pin Holes. Pin-holes shall be bored true to gauges, smooth and straight; at right angles to the axis of the member and parallel to each other, unless otherwise called for. The boring shall be done after the member is riveted up.

227. Variation in Pin Holes. The distance center to center of pin holes shall be correct within $\frac{1}{32}$ in. and the diameter of

the holes not more than $\frac{1}{50}$ in. larger than that of the pin, for pins up to 5 in. diameter, and $\frac{1}{32}$ in. for larger pins.

228. Pins and Rollers. Pins and rollers shall be acurately turned to gauges and shal be straight and smooth and entirely free from flaws.

229. Pilot Nuts. Pilot and driving nuts shall be furnished for each size of pin in such numbers as may be ordered.

230. Screw Threads. Screw threads shall make tight fits in the nuts and shall be U.S. standard, except above the diameter of $1\frac{3}{8}$ in., when they shall be made with six threads per inch.

231. Bed Plates. Expansion bed plates and vertical webs of pedestals shall be planed true and smooth. Cast wall or bed plates shall be planed top and bottom. The cut of the planing tool shall correspond with the direction of expansion.

232. Annealing. Steel, except in minor details, which has been partially heated shall be properly annealed. (Par. 233.)

233. Steel Castings. All steel castings shall be annealed.

234. Welds. Welds in steel will not be allowed.

235. Shipping Details. Pins, nuts, bolts, rivets, and other small details shall be boxed or crated.

236. Weight. The weight of every piece and box shall be marked on it in plain figures.

237. Finished Weight. Payment for pound price contracts shall be by scale weight. No allowance over 2 per cent of the total weight of the structure, as computed from the plans, will be made for excess weight.

PART VI

INSPECTION, PAINTING, AND ERECTION

Inspection and Testing

238. **Copies of Mill Orders.** The purchaser shall be furnished copies of mill orders and no material shall be rolled, or work done, before the purchaser has been notified where the orders have been placed, so that he may arrange for the inspection.

239. **Facilities for Mill Inspection.** The manufacturer shall furnish all facilities for inspecting and testing the weight and quality of all material at the mill where it is manufactured. He shall furnish a suitable testing machine for testing the specimens, as well as prepare the pieces for the machine, free of cost.

240. **Access to Mills.** When an inspector is employed by the purchaser to inspect material at the mills, he shall have full access, at all times, to all parts of mills where material to be inspected by him is being manufactured.

241. **Facilities for Shop Inspection.** The manufacturer shall furnish all facilities for inspecting and testing the weight and quality of workmanship at the shop where material is manufactured. He shall furnish a suitable testing machine for testing full-sized members, if required.

242. **Starting Work in Shops.** The purchaser shall be notified well in advance of the start of the work in the shop in order that he may have an inspector on hand to inspect material and workmanship.

243. **Access to Shop.** When an inspector is employed by the purchaser he shall have full access, at all times, to all parts of the shop where material under his inspection is being manufactured.

244. **Accepting Material or Work.** The inspector shall stamp each piece accepted with a private mark. Any piece not so marked may be rejected at any time and at any stage of

the work. If the inspector, through an oversight or otherwise, has accepted material or work which is defective or contrary to the specifications, this material, no matter in what stage of completion, may be rejected by the purchaser.

245. **Shop Plans.** The purchaser shall be furnished complete shop plans.

246. **Shipping Invoices.** Complete copies of shipping invoices shall be furnished to the purchaser with each shipment.

247. **Test to Prove Workmanship.** Full-sized tests on eye-bars and similar members, to prove the workmanship, shall be made at the manufacturer's expense and shall be paid for by the purchaser at contract price if the tests are satisfactory. If the tests are not satisfactory the members represented by them will be rejected.

248. **Eye-Bar Tests.** In eye-bar tests the fracture shall be silky, the elongation in 10 ft., including the fracture, shall not be less than 15 per cent; and the ultimate strength and true elastic limit shall be recorded. (Par. 224.)

PAINTING

249. **Cleaning.** Steelwork, before leaving the shop, shall be thoroughly cleaned and given one good coating of pure linseed oil, or such other paint as may be called for in the contract, well worked into all joints and open spaces.

250. **Contact Surfaces.** In riveted work the surfaces coming in contact shall each be painted before being riveted together.

251. **Inaccessible Surfaces.** Pieces and parts which are not accessible for painting after erection, including tops of stringers, eye-bar heads, ends of posts and chords, etc., shall have a good coat of paint before leaving the shop.

252. **Condition of Surfaces.** Painting shall be done only when the surface of the metal is perfectly dry. It shall not be done in wet or freezing weather, unless protected under cover.

253. **Machine-Finished Surfaces.** Machine-finished surfaces shall be coated with white lead and tallow before shipment or before being put out into the open air.

254. **Painting Omitted.** Rods, wires, hoops, etc., used for concrete reinforcement and all other steelwork, or parts of steelwork, entirely embedded in concrete shall not be painted.

255. Painting after Erection. After the structure is erected the metal work shall be cleaned of scale, rust, and dirt, and then thoroughly and evenly painted.

Steelwork in buildings, or where otherwise protected from exposure, shall have one additional coat of paint, mixed with pure linseed oil, or as specified by the Engineer.

Steelwork in bridges, or other exposed structures, shall have two additional coats of paint as specified.

The various coats of paint shall be of distinctly different shades or colors, and one coat must be allowed to dry before the next is applied.

ERECTION

256. When the Contractor Erects. Whenever the contractor is required to do the erection this requirement shall be specifically stated in the contract.

The erection will then include the removal of any existing structure, all necessary hauling, the unloading of the materials and their proper care until the completion and acceptance of the work, as specified in Pars. 257 to 263.

257. Removal of Old Structure. Whenever new structures are to replace existing ones the latter shall be carefully taken down, marked and scheduled to facilitate re-erection, and removed by the contractor to some place as specified in the contract.

258. Interruption of Traffic. All operations shall be so conducted as not to impede or interrupt the work of other contractors, the traffic of any railroad, nor close any thoroughfare or waterway, nor conflict with any law, regulation, or ordinance of any properly constituted authority.

259. Permits. Before commencing operations the contractor shall, at his own expense, obtain all necessary permits and comply with their requirements.

260. Erection. The contractor shall furnish, at his own expense, all necessary staging, falsework, materials, and tools, and shall erect the structure complete and paint the same. (Pars. 254, 255.)

In the case of a bridge, or trestle, he shall furnish and frame all floor timbers, guard rails, handrailings, trestle timbers, etc., complete ready for the rails.

Wherever necessary he shall drill holes in the masonry,

properly place all anchor bolts and securely attach them to the masonry by Portland cement, or otherwise.

261. **Safeguards and Damages.** The contractor shall furnish, at his own expense, all watchmen, guards, signals, night lights, etc., for the prevention of accidents, and be responsible for the safety of the structure; and he shall assume full responsibility for all accidents to men, animals, and materials before the completion and final acceptance of the structure and shall indemnify the purchaser for any and all claims for damages arising therefrom.

262. **Defective Work.** The contractor shall, at his own expense, remove, rebuild, or make good any damaged material or defective work, even if the same through an oversight or otherwise has been previously accepted.

263. **Clearing-up.** When the erection is completed the contractor shall, at his own expense, remove all falsework, rubbish, and other useless material caused by his operations.

264. **When the Purchaser Erects.** In case the purchaser erects the work the material shall be delivered on cars at the railway station mentioned in the contract.

Any extra cost incurred by the purchaser, during the erection, due to defective material or workmanship, shall be borne by the contractor.

PART VII

STRUCTURAL TIMBER

QUALITY

265. Kinds of Timber. All timber for structures carrying live loads shall preferably be of longleaf yellow pine, Douglas fir, white oak or western hemlock; for other structures short-leaf yellow pine, spruce, white pine or other equivalent good timber may be used. Chestnut and Norway pine may be used for piles.

266. Quality of Timber. All timber must be cut within eighteen (18) months of the time of delivery, from sound trees and sawed to standard size. (Par. 267.) It must be close grained and solid, free from defects such as injurious ring shakes and crooked grain, unsound knots, knots in groups, decay, large pitch pockets, or other defects that will materially impair its strength or fitness for the purpose intended. (Pars. 269 to 274.)

267. Size of Sawed Timber. All timber shall be sawed true, out of wind and shall, when dry, not measure scant in thickness more than the following:

$\frac{1}{16}$ in., for flooring and boards up to $1\frac{1}{2}$ in. thick, rough size;
$\frac{1}{8}$ in., for planking from $1\frac{3}{4}$ in. to $5\frac{3}{4}$ in. thick, rough size; and
$\frac{1}{4}$ in., for dimension timber from 6 in. thick and up, rough size.

268. Dressing of Sawed Timber. When dressed timber over $1\frac{1}{2}$ in. in thickness is required the dimensions specified shall refer to rough sizes, unless otherwise mentioned.

A reduction of not more than $\frac{1}{8}$ in., beyond that specified in Par. 267 will be allowed for each planed surface.

269. Shingles. Shingles shall be of pine, cedar, or cypress, as specified in the contract. They shall be from 16 to 18 in. in length, from 4 to 6 in. wide, $\frac{1}{16}$ in. in thickness at the tip and from

$\frac{7}{16}$ to $\frac{1}{2}$ thick at the butt. They shall, in the first 10 in. from the butt, be absolutely free from sap, knots, or other defects.

270. Piles. Timber piles shall preferably be of Southern (longleaf or shortleaf) yellow pine, white oak, Norway pine or cedar, as specified in the contract.

They shall be cut from sound, live trees, shall be straight and free from wind-shakes, large knots, decay, and other important defects. The diameter of round piles near the butt shall not be less than 14 in. or more than 16 in., and at the tip, of piles under 40 ft. in length, not less than 8 in., or less than 6 in. in any case.

They shall taper evenly from butt to tip and shall be so straight that a straight line, drawn from center to center of ends, shall at no point fall outside of the circumference.

All piles shall be cut square at ends and they shall be stripped of their bark. (Par. 277.)

271. Flooring. Flooring shall preferably be of rift shortleaf yellow pine or maple and shall be furnished in two grades (prime and common) and usually in lengths between 4 and 16 ft. and not over $2\frac{1}{2}$-in. face. The thickness of flooring shall be understood to be the thickness of the finished material after dressing.

The exact kind of wood, grade, width, and thickness shall be specified in the contract.

(*a*) *Prime Flooring.* Prime flooring shall be edge grained, kiln dried, matched, tongued and grooved, well manufactured so as to be free from planer's marks, edge splinters, grain slivers, etc. It shall show one face all heart and shall be free from knots, shakes, sap, and pitch pockets.

(*b*) *Common Flooring.* Common flooring shall be like prime flooring except that the material may show one knot, not over 1 in. in diameter, to every 4 ft. in length, also unimportant pitch streaks and sap stains.

272. Ceiling and Wainscoting. Ceiling and wainscoting shall be graded as the flooring, but shall in addition be double beaded and very carefully dressed.

273. Planks and Scantling. Planks and scantling, when used for floors, struts, cross and sway bracing, shall show one face all heart, the other face and two sides shall show not less than 75 per cent heart, measured across the face or sides any-

where in the piece. It shall be free from knots 1½ in. in diameter and over.

When used for other purposes it shall be square edged, free from knots 2½ in. in diameter and over, and wanes not extending over 5 per cent of the surface area may be allowed in 5 per cent of the total number of pieces in any one size.

274. **Dimension Timber.** Dimension timber, when used as beams, bridge joists, or stringers, caps, and sills in trestles and posts, shall show not less than 75 per cent heart on each of the four sides, measured across each side anywhere in the length of the piece. No loose knots, or knots greater than 2½ in. in diameter or over one-quarter (¼) the width of the face of the stick in which they occur, will be allowed. Knots must not be in groups, or be located within 3 in. of the edges.

When used for other purposes it shall be square edged, except it may have 1 in. wane on one corner and ring shakes must not extend over one-eighth (⅛) of the length of the piece.

Unit Stresses

275. **Timber in Buildings and Highway Bridges.** The maximum stresses due to the combined effect of dead, snow, wind, and live loads, including bending and impact, if any, shall not exceed the following values *in pounds per square inch:*

Timber.	Bending Extreme Fibers.	Tension		Compression.			Shearing.	
		With Grain.	Across Grain.	With Grain.	Under 15 Diam.	Across Grain.	With Grain.	Across Grain.
Douglas fir	1100	1000	....	1200	900	300	160	800
Hemlock, western	1000	800	....	1000	750	200	150	700
Oak, white	1000	1000	200	1300	975	450	160	1000
Pine, white	800	800	50	1000	750	150	100	600
" yellow, longleaf.	1200	1200	60	1300	975	260	180	1200
" " shortleaf.	1000	900	50	1100	825	180	170	1000
Spruce	900	800	50	1100	825	180	100	600

For columns whose length does not exceed 15d the above values, given for "Compression under 15 diameters," may be used.

When the length of the column exceeds $15d$ the above values, given for "Compression with grain," shall be reduced as follows:

$$S=c-\frac{cl}{60d},$$

where S = allowable working stress per square inch;
c = " compression with grain " given above;
l = unsupported length of column in inches;
d = least width of column in inches;

and maximum $$\frac{l}{d}=45.$$

276. Timber in Railroad Bridges and Trestles. The maximum stresses due to the combined effect of dead and live loads, lateral and longitudinal forces, including bending and impact, shall not exceed the following values *in pounds per square inch.*

Timber.	Bending Extreme Fibers.	Tension.		Compression.			Shearing.	
		With Grain.	Across Grain.	With Grain.	Under 15 Diam.	Across Grain.	With Grain.	Across Grain.
Douglas fir	1800	1600	....	2000	1400	500	260	1300
Hemlock, western	1600	1300	....	1600	1120	320	250	1150
Oak, white	1600	1600	325	2100	1470	750	260	1600
Pine, white	1300	1300	80	1600	1120	250	160	1000
" yellow, longleaf	2000	2000	100	2100	1470	430	300	2000
" " shortleaf	1600	1500	80	1800	1260	300	280	1600
Spruce	1500	1300	80	1800	1260	300	160	1000

For columns whose length does not exceed $15d$ the above values, given for " Compression under 15 diameters," may be used.

When the length of the column exceeds $15d$ the above values, given for " Compression with grain," shall be reduced as follows:

$$S=c_1-\frac{c_1 l}{50d},$$

where S = allowable working stress per square inch;
c_1 = " compression with grain " given above;
l = unsupported length of column in inches;
d = least width of column in inches;

and maximum $$\frac{l}{d}=35.$$

277. Piles. The maximum load per pile due to the combined effect of dead and live loads, lateral and longitudinal forces, including impact, if any, shall not exceed the following:

$$P=\frac{2.5WH}{(s+1)},$$

where P = allowable pressure in pounds per pile, limited as per below;
W = weight of drop hammer in pounds;
H = height of drop in feet;
s = average sinking in inches due to the last five blows when squarely struck.

When the piles are driven through wet and loose soil to a good bearing the pressure shall not exceed 300 lbs. per sq.in. of their average cross-section. When driven through a firm soil this pressure may be increased to 600 lbs. (Par. 270.)

Details of Design

278. Flooring and Joists (Buildings). Floor planks and floor joists in buildings, carrying plastering, shall be proportioned with regard to their stiffness, limiting their deflection to one-three-hundred-and-sixtieth ($\frac{1}{360}$) of the span.

All other timber in buildings may be proportioned with regard to its strength.

279. Flooring (Highway Bridges). Floor planks for the roadway, when a single thickness is used shall have a minimum thickness of 3 in., shall be laid with $\frac{1}{4}$-in. open spaces and shall be securely spiked to the joists.

Footwalk planks shall have a minimum thickness of 2 in., shall be at least 6 in. wide and shall be spaced with $\frac{1}{2}$-in. openings.

Where an additional wearing surface is being used, the minimum thickness of which shall be $1\frac{1}{2}$ in., the thickness of the

supporting plank may be reduced to $2\frac{1}{2}$ in., in which case the latter shall be laid diagonally with $\frac{1}{2}$-in. openings.

All floor planks shall be laid with the heart side down.

280. Joists (Highway Bridges). The minimum size of joists shall be $3'' \times 12''$. They shall be notched over their bearings at least $\frac{1}{2}$ in., bringing the top surfaces to exact level. Where they rest on top of the floor beams the intermediate joists shall lap by each other over the full width of same, with $\frac{1}{2}$ in. open space for circulation of air, whereas the outside joists shall have their outer faces flush from end to end of span.

If the floor plank be continuous each joist may be assumed to carry only two-thirds ($\frac{2}{3}$) of the concentrated load.

The maximum spacing for wooden joists shall be 2 ft. 6 in.

281. Wheel Guards (Highway Bridges). There shall be a wheel-guard on each side of the roadway having a minimum size of $4'' \times 6''$, laid on flat, and blocked up on shims $2'' \times 6''$ and 12 in. long. The shims shall have a maximum spacing of 5 ft. from center to center. The wheel guards shall be spliced with half-and-half joints 6 in. long over a shim and shall be fastened to the joist beneath with a three-quarter ($\frac{3}{4}$) in. bolt passing through the center of each shim.

282. Handrailing (Highway Bridges). The posts shall be $6'' \times 4''$, spaced not more than 5 ft. apart, and shall be firmly fastened. There shall be two lines of railing of $2'' \times 6''$ plank, the upper line of which shall be placed on flat and the lower one on edge.

283. Cross Ties (Railroad Bridges). The cross ties shall be of such size as to give the requisite resistance to bending, under the assumption that the maximum load is distributed equally over three ties and that the impact equals 100 per cent.

Every tie shall be notched down not less than $\frac{1}{2}$ in. and be brought to a full and even bearing upon the stringers, and every third tie shall be secured thereto by a $\frac{3}{4}$-in. hook bolt.

The minimum sizes of cross ties shall be:

(*a*) For electric railroads $6'' \times 8'' \times 8'$ (laid on flat); and,

(*b*) For steam railroads $8'' \times 8'' \times 10'$.

The ties shall be spaced 14 in. center to center, with a free opening of not more than 6 in., or less than 4 in.

On curves the super-elevation of the outer rail shall be obtained by using beveled ties.

284. Guard Rails (Railroad Bridges). The minimum size of the outer guard rails shall be 6″×8″ (laid on flat) and so placed that their inner faces are not less than 3 ft. 3 in., or more than 3 ft. 6 in., from center of track.

The minimum size of the inner guard rails shall be 6″×8″ (laid on flat) and so placed that their outer faces are not less than 1 ft. 11 in., or more than 2 ft. from center of track.

All guard rails shall be continuous over piers and abutments; they shall be spliced with half-and-half joints over a tie, shall be notched 1 in. over every tie and shall be fastened to every third tie and through the splice by a three-quarter (¾) in. bolt. The floor system shall be fastened to the supporting girders by a three-quarter (¾) in. hook bolt through every third tie.

All heads or nuts of bolts on the upper faces of guard rails shall be countersunk into the wood and placed in a cup washer.

285. Pile Trestles. For heights less than 30 ft. pile trestles may be used, and their spacing, center to center of bents, shall not exceed 15 ft. Each bent whose height exceeds 10 ft. shall be braced transversely and, if it exceeds 15 ft., shall in addition be braced longitudinally in at least every fifth panel.

286. Framed Trestles. For trestles of greater height than 30 ft. framed bents shall be used. They shall be supported upon foundations of concrete piers, timber sills, or piles. All framed bents shall be braced transversely and, in every alternate panel, longitudinally.

287. Trestle Stringers. Wherever there are several timber stringers under each rail they shall be placed symmetrically under same. The stringers shall break joints over the bents, shall be securely fastened thereto, and shall be separated from each other by means of cast-iron fillers one-half (½) in. thick spaced not over 5 ft. apart.

PART VIII

CEMENT

The following specifications for cement were adopted August 15, 1908, as standard by the American Society for Testing Materials.

General Observations

288. (*a*) These remarks (Pars. 288–293) have been prepared with a view of pointing out the pertinent features of the various requirements and the precautions to be observed in the interpretation of the results of the tests.

(*b*) The committee would suggest that the acceptance or rejection under these specifications be based on tests made by an experienced person having the proper means for making the tests.

289. Specific Gravity. Specific gravity is useful in detecting adulterations. The results of tests of specific gravity are not necessarily conclusive as an indication of the quality of a cement, but when in combination with the results of other tests may afford valuable indications.

290. Fineness. The sieves should be kept thoroughly dry.

291. Time of Setting. Great care should be exercised to maintain the test pieces under as uniform conditions as possible. A sudden change or wide range of temperature in the room in which the tests are made, a very dry or humid atmosphere, and other irregularities, vitally affect the rate of setting.

292. Tensile Strength. Each consumer must fix the minimum requirements for tensile strength to suit his own conditions. They shall, however, be within the limits stated.

293. Constancy of Volume:

(*a*) The tests for constancy of volume are divided into two classes, the first normal, the second accelerated. The latter should be regarded as a precautionary test only, and not infallable. So many conditions enter into the

making and interpreting of it that it should be used with extreme care.

(*b*) In making the pats the greatest care should be exercised to avoid initial strains due to molding or to too rapid drying-out during the first twenty-four hours. The pats should be preserved under the most uniform conditions possible, and rapid changes of temperature should be avoided.

(*c*) The failure to meet the requirements of the accelerated tests need not be sufficient cause for rejection. The cement may, however, be held for twenty-eight days, and a retest made at the end of that period, using a new sample. Failure to meet the requirements at this time should be considered sufficient cause for rejection, although in the present state of our knowledge it cannot be said that such failure necessarily indicates unsoundness, nor can the cement be considered entirely satisfactory simply because it passes the tests.

Specifications

294. General Conditions:

(*a*) All cement shall be inspected.

(*b*) Cement may be inspected either at the place of manufacture or on the work.

(*c*) In order to allow ample time for inspection and testing, the cement should be stored in a suitable weather-tight building having the floor properly blocked or raised from the ground.

(*d*) The cement shall be stored in such a manner at to permit easy access for proper inspection and identification of each shipment.

(*e*) Every facility shall be provided by the contractor and a period of at least twelve days allowed for the inspection and necessary tests.

(*f*) Cement shall be delivered in suitable packages with the brand and name of manufacturer plainly marked thereon.

(*g*) A bag of cement shall contain 94 lbs. of cement net. Each barrel of Portland cement shall contain 4 bags, and each barrel of natural cement shall contain 3 bags of the above net weight.

(*h*) Cement failing to meet the 7-day requirements may be held awaiting the results of the 28-day tests before rejection.

(*i*) All tests shall be made in accordance with the methods proposed by the Committee on Uniform Tests of Cement of the American Society of Civil Engineers, presented to the Society, January 21, 1903, and amended January 20, 1904, and January 15, 1908, with all subsequent amendments thereto.

(*j*) The acceptance or rejection shall be based on the following requirements:. (Pars. 295 to 306.)

Natural Cement

295. **Definition.** This term shall be applied to the finely pulverized product resulting from the calcination of an argillaceous limestone at a temperature only sufficient to drive off the carbonic acid gas.

296. **Fineness.** It shall leave by weight a residue of not more than 10 per cent on the No. 100, and 30 per cent on the No. 200 sieve.

297. **Time of Setting.** It shall not develop initial set in less than 10 minutes, and shall not develop hard set in less than 30 minutes, or in more than 3 hours.

298. **Tensile Strength.** The minimum requirements for tensile strength for briquettes 1 in. square in cross-section shall be within the following limits, and shall show no retrogression in strength within the periods specified:*

NEAT CEMENT

Age.	Strength.
24 hours in moist air	50–100 lbs.
7 days (1 day in moist air, 6 days in water)	100–200 "
28 days (1 " " 27 " ")	200–300 "

ONE PART CEMENT, THREE PARTS STANDARD SAND

7 days (1 day in moist air, 6 days in water)	25–75 lbs.
28 days (1 " " 27 " ")	75–150 "

* For example, the minimum requirement for the 24-hour neat cement test should be some specified value within the limits of 50 and 100 lbs., and so on for each period stated.

If the minimum strength is not specified, the mean of the above values shall be taken as the minimum strength required.

299. Constancy of Volume. Pats of neat cement about 3-in. in diameter, ½-in. thick at center, tapering to a thin edge, shall be kept in moist air for a period of 24 hours.

(*a*) A pat is then kept in air at normal temperature.

(*b*) Another is kept in water maintained as near 70°, F. as practicable.

(*c*) These pats are observed at intervals for a least 28 days, and, to satisfactorily pass these tests, should remain firm and hard and show no signs of distortion, checking, cracking, or disintegrating.

Portland Cement

300. Definition. This term applies to the finely pulverized product resulting from the calcination to incipient fusion of an intimate mixture of properly proportioned argillaceous and calcareous materials, and to which no addition greater than 3 per cent. has been made subsequent to calcination.

301. Specific Gravity. The specific gravity of the cement, ignited to a low red heat, shall be not less than 3.10, and the cement shall not show a loss on ignition of more than 4 per cent.

302. Fineness. It shall leave by weight a residue of not more than 8 per cent on the No. 100, and not more than 25 per cent on the No. 200 sieve.

303. Time of Setting. It shall not develop initial set in less than 30 minutes, and must develop hard set in not less than 1 hour, nor more than 10 hours.

304. Tensile Strength. The minimum requirements for tensile strength for briquettes 1 in. square in section shall be within the periods specified.*

NEAT CEMENT

Age.	Strength.
24 hours in moist air	150–200 lbs.
7 days (1 day in moist air, 6 days in water)	450–550 "
28 days (1 " " 27 " ")	550–650 "

* For example, the minimum requirement for the 24-hour neat cement test should be some specified value within the limits of 150 and 200 lbs., and so on for each period stated.

ONE PART CEMENT, THREE PARTS STANDARD SAND

7 days (1 day in moist air, 6 days in water)	150–200 lbs.
28 days (1 " " 27 " ")	200–300 "

If the minimum strength is not specified, the mean of the above values shall be taken as the minimum strength required.

305. Constancy of Volume. Pats of neat cement about 3 in. in diameter, ½ in. thick at center, and tapering to a thin edge, shall be kept in moist air for a period of 24 hours.

(*a*) A pat is then kept in air at normal temperature and observed at intervals for at least 28 days.

(*b*) Another pat is kept in water maintained as near 70° F. as practicable, and observed at intervals for at least 28 days.

(*c*) A third pat is exposed in any convenient way in an atmosphere of steam, above boiling water, in a loosely closed vessel for 5 hours.

(*d*) These pats, to satisfactorily pass the requirements, shall remain firm and hard and show no signs of distortion, checking, cracking, or disintegrating.

306. Sulphuric Acid and Magnesia. The cement shall not contain more than 1.75 per cent of anhydrous sulphuric acid (SO_3), nor more than 4 per cent of magnesia (MgO).

PART IX

PORTLAND-CEMENT CONCRETE

THE following specifications for Portland-cement concrete were adopted in 1904, as standard by the American Railway Engineering and Maintenance of Way Association, see Proceedings, Vol. V.

307. **Cement.** The cement shall be Portland, either American or foreign, which will meet the requirements of the standard specifications adopted by the American Society for Testing Materials. (See Part VIII.)

308. **Sand.** The sand shall be clean, sharp, coarse, and of grains varying in size. It shall be free from sticks and other foreign matter, but it may contain clay or loam not to exceed 5 per cent. Crusher dust, screened to reject all particles over ¼ in. in diameter, may be used instead of sand, if approved by the Engineer.

309. **Stone.** The stone shall be sound, hard, and durable, crushed to sizes not exceeding 2 in. in any direction. For reinforced concrete, the sizes usually are not to exceed ¾ in. in any direction, but may be varied to suit the character of the reinforcing material.

310. **Gravel.** The gravel shall be composed of clean pebbles of hard and durable stones of sizes not exceeding 2 in. in diameter, free from clay and other impurities except sand. When containing sand in any considerable quantity, the amount per unit of volume of gravel shall be determined accurately to admit of the proper proportion of sand being maintained in the concrete mixture.

311. **Water.** The water shall be clean and reasonably clear, free from sulphuric acid and strong alkalies.

312. **Mixing by Hand:**

(a) Tight platforms shall be provided of sufficient size to accommodate men and materials for the progressive

and rapid mixing of at least two batches of concrete at the same time. Batches shall not exceed 1 cubic yard each, and smaller batches are preferable, based upon a multiple of the number of sacks to the barrel.

(*b*) Spread the sand evenly upon the platform, then the cement upon the sand, and mix thoroughly until of an even color. Add all the water necessary to make a thin mortar, and spread again; add the gravel if used, and finally the broken stone, both of which, if dry, should first be thoroughly wet down. Turn the mass with shovels or hoes until thoroughly incorporated, and until all the gravel and stone is covered with mortar, which will probably require the mass to be turned four times.

(*c*) Another method, which may be permitted at the option of the engineer in charge, is to spread the sand, then the cement, and mix dry; then the gravel or broken stone, add water, and mix thoroughly as above.

313. **Mixing by Machine.** A machine mixer shall be used wherever the volume of work will justify the expense of installing the plant. The necessary requirements for the machine shall be that a precise and regular proportioning of materials can be controlled, and the product as delivered shall be of the required consistency and be thoroughly mixed.

314. **Consistency.** The concrete shall be of such consistency that when dumped in place it will not require much tamping. It shall be spaded down, and be tamped sufficiently to level it off, after which the water should rise freely to the surface.

315. **Forms:**

(*a*) Forms shall be well built, substantial and unyielding, properly braced or tied together by means of wire or rods, and shall conform to the lines given.

(*b*) For all important work, the lumber used for face work shall be dressed on one side and both edges, and shall be sound and free from loose knots, secured to the studding or uprights in horizontal lines.

(*c*) For backing and other rough work, undressed lumber may be used.

(*d*) Where corners of the masonry and other projections liable to injury occur, suitable moldings shall be

placed in the angles of the forms to round or bevel them off.

(*e*) Lumber once used in forms shall be cleaned before being used again.

(*f*) The forms must not be removed within 36 hours after all the concrete in that section has been placed. In freezing weather, they must remain until the concrete has had sufficient time to become thoroughly hardened.

(*g*) In dry but not freezing weather, the forms shall be drenched with water before the concrete is placed against them.

316. Depositing:

(*a*) Each layer should be left somewhat rough to insure bonding with the next layer above; and, if the concrete has already set, it shall be thoroughly cleaned by scrubbing with coarse brushes and water before the next layer is placed upon it.

(*b*) Concrete shall be deposited in the molds in layers of such thickness and position as shall be specified by the Engineer in charge. Temporary planking shall be placed at the ends of partial layers, so that none shall run out to a thin edge. In general, excepting in arch work, all concrete must be deposited in horizontal layers of uniform thickness throughout.

(*c*) The work shall be carried up in sections of convenient length and the sections shall be completed without intermission.

(*d*) In no case shall work on a section stop within 18 in. of the top.

(*e*) Concrete shall be placed immediately after mixing, and any having an initial set shall be rejected.

317. Expansion Joints:

(*a*) In exposed work, expansion joints may be provided at intervals of 30 to 100 ft., as the character of the structure may require.

(*b*) A temporary vertical form or partition of plank shall be set up, and the section behind shall be completed as though it were the end of the structure. The partition shall be removed when the next section is begun, and the new concrete shall be placed against the old without

mortar flushing. Locks shall be provided, if directed or called for by the plans.

(*c*) In reinforced concrete the length of these sections may be materially increased at the option of the Engineer.

318. **Facing:**

(*a*) The facing may be made by carefully working the coarse stone back from the form by means of a shovel, bar, or similar tool, so as to bring the excess mortar of the concrete to the face.

Or,

(*b*) About 1 in. of mortar (not grout) of the same proportion as used in the concrete may be placed next to the forms immediately in advance of the concrete, in order to secure a perfect face.

(*c*) Care must be taken to remove from the inside of the forms any dry mortar in order to secure a perfect face.

319. **Proportions.** The proportions of the materials in the concrete shall be as specifically called for by contract, or as set forth herein, upon the lines left for that purpose, the volume of cement to be based upon the actual cubic contents of 1 barrel of specified weight.

Structure.	Parts by Volume			
	Cement.	Sand.	Gravel.	Broken Stone.

320. **Finishing:**

(*a*) After the forms are removed, which should generally be as soon as possible after the concrete is sufficiently hardened, any small cavities or openings in the face shall be neatly filled with mortar, if necessary in the opinion of the Engineer. Any ridges due to cracks or joints in the lumber shall be rubbed down with chisel or wooden float. The entire face may then be washed with a thin grout of the consistency of whitewash,

mixed in the same proportion as the mortar of the concrete. The wash shall be applied with a brush. The earlier the above operations are performed the better will be the result.

(*b*) The tops of bridge seats, pedestals, copings, wing walls, etc., when not finished with natural stone coping, shall be finished with a smooth surface composed of one part cement to two parts of granite or other suitable screenings or sand, applied in a layer ½ to 1 in. thick. This must be put in place with the last course of concrete.

321. **Waterproofing.** Where waterproofing is required, a thin coat of mortar or grout shall be applied for a finishing coat, upon which shall be placed a covering of suitable waterproofing material.

322. **Freezing Weather.** Ordinarily concrete to be left above the surface of the ground shall not be constructed in freezing weather. Portland-cement concrete may be built under these conditions by special instructions. In this case the sand, water, and broken stone shall be heated; and in severe cold, salt shall be added in the proportion of about 2 lbs. per cubic yard.

323. **Reinforced Concrete.** (See Part X.)

PART X

REINFORCED CONCRETE

General Requirements

324. Preparation of Plans. All plans shall be prepared, and drawn to a scale sufficiently large so as to show clearly the quantity and the exact position of all reinforcement; the method of its anchorage, where continuity or extra bonding are required; and in short all details of parts affecting strength or appearance.

325. Adherence to Plans. The contractor shall, during construction, adhere strictly to the plans, as the strength of the finished structure depends upon this; and the inspector shall not be allowed to make any changes therein without the written authority of the engineer.

326. Placing of Forms:

(*a*) The falsework and forms shall be substantial and unyielding, properly braced or tied together by means of wire or rods, and shall be so designed that the concrete will conform to the proper dimensions and contours.

(*b*) The timber used shall not be too dry, as a free absorption of moisture will cause swelling and consequent deformation of the concrete; it shall be planed smooth on both edges and one side, shall be covered with a coating of oil, soap, limewash or other substance to prevent the concrete from adhering to the surface, and shall have all joints closed so as to prevent the leakage of grout.

(*c*) In general the forms shall be simple of construction, easy of erection, maintenance, and removal, and they shall frequently be inspected during the progress of the work that perfect alignment may be maintained.

(*d*) All forms having been previously used shall be thoroughly cleansed and prepared before being used again.

327. Metal Reinforcement. No metal reinforcement used in concrete shall be painted, but shall be free from dirt, oil, or

grease. All mill scale shall be removed by hammering the metal, or preferably by pickling the same in a weak solution of muriatic acid.

328. **Placing of Reinforcement.** The metal reinforcement shall be placed and kept during the deposition and tamping of the concrete in the proper position. Whenever it is practicable it shall be placed in position first. This can usually be done where the metal occurs in the bottom of the forms, by supporting it on transverse wires or otherwise.

329. **Ingredients.** The contract covering any reinforced concrete work shall specifically state the quality of the cement and the aggregates and, if possible, the particular brands of cement, sand, gravel, or broken stone to be used; shall state the exact proportions of cement and aggregates and the approximate proportion of water to be mixed, and the required strength in compression to be attained in 28 days by test cylinders 8 in. in diameter and 16 in. long.

Methods of measurements of the proportions of the various ingredients, including the water, shall be used, which will secure separate uniform measurements at all times, preferably by weight.

330. **Mixing by Hand.** (See Par. 312.)

331. **Mixing by Machine.** (See Par. 313.)

332. **Consistency.** The materials should be mixed wet enough to produce a concrete of such a consistency as will flow into the forms and about the metal reinforcement, and, at the same time, can be conveyed from the mixer to the forms without separation of the coarse aggregates from the mortar.

333. **Placing of Concrete:**

(*a*) Before placing the concrete care shall be taken to see that the forms are thoroughly wetted and the space to be occupied by the concrete is free from débris.

(*b*) Great care must also be taken to insure the coating of the metal with cement mortar and the thorough flushing of the bottoms of the forms with same; after which the concrete must be deposited rapidly, thoroughly compacting it around the metal.

(*c*) Concrete, after the addition of water to the mix, shall be handled rapidly, in as small masses as is practicable, from the place of mixing to the place of final deposit.

(*d*) No concrete having an initial set shall be used, nor shall the retempering of mortar or concrete (i.e., remixing with water after it has partially set) be permitted.

(*e*) Where the metal reinforcement occurs in several layers the concrete shall be deposited in equal layers and rammed separately. Otherwise the concrete shall be spread in horizontal layers not exceeding 4 in. in slabs, or 6 in. in any case.

(*f*) The concrete shall be deposited in a manner that will permit the most thorough compacting, such as can be obtained by working with a straight shovel or slicing tool kept moving up and down till all the ingredients have settled in their proper place by gravity and the surplus water is forced to the surface.

(*g*) In columns having circumferential reinforcement the concrete shall preferably be introduced by means of a tremie or tube, in order to prevent the ingredients from sorting in layers. To prevent settlement or shrinkage in freshly made columns a period of at least two hours shall elapse before any girder or beam over them may be commenced.

(*h*) In depositing concrete under water special care shall be exercised to prevent the cement from floating away and to prevent the formation of laitance; when laitance has formed it shall be removed before placing fresh concrete.

(*i*) When work is resumed concrete previously placed shall be roughened, thoroughly cleansed of foreign material and laitance, drenched and slushed with a mortar consisting of 1 part Portland cement and 2 parts sand.

(*j*) The faces of concrete exposed to premature drying should be kept wet for a period of at least 7 days after molding.

334. Freezing Weather. Concrete for reinforced structures shall not be mixed or deposited at a freezing temperature, except under special instruction. In this case the sand, water, and broken stone shall be heated, but no salt shall be added.

Effective means shall be provided to prevent the concrete from freezing until it has thoroughly hardened.

335. Removal of Forms:

(*a*) The time for removal of forms and shores, being an extremely important consideration, shall be determined in each case by the engineer after inspection. As a guide the following important determinants are mentioned; size of structure and general dimensions of parts; methods of mixing and proportions of mixture; whether slow or quick-setting cements are used; atmospheric conditions; importance of live loading and its ratio to the dead load; length of period between the removal of forms and shores and the time when the maximum loading may be attained, etc. But in any case the supporting shores shall be left in place until their removal is permitted by the engineer.

(*b*) The minimum time for the removal of *Forms* (not the supporting shores shall be as follows:

For *Bottom of Slabs* 4 days, for spans of 4 ft. or less, plus 1 day extra for each additional foot of span.

For *Sides and Beams and Girders* 7 days.

For *Columns* 4 days.

For *Bridge Arches* 28 days.

(*c*) The minimum time for the removal of *Shores* shall be as follows:

For *Bottoms of Beams and Girders* 21 days, for spans of 10 ft. or less, plus one-half ($\frac{1}{2}$) day for each additional foot of span.

The original shores must in no case be taken down, replaced or disturbed, until permitted by the Engineer.

(*d*) When frosty weather occurs during the above periods an extension of time shall be made equal to its duration.

(*e*) During the setting and before the removal of forms no extraneous loading shall be placed upon the concrete.

(*f*) The forms shall be removed with care so as not to deface the structure or to disturb the remaining supports.

Loads

336. Dead Load. The dead load consists of:

(*a*) The weight of the reinforced concrete, which shall be taken at 150 lbs. per cubic foot.

(*b*) The weight of the roof covering, flooring, paving, or ballast, if any. (For weight of same see Pars. 3, 4, 5, 59, 109.)

(*c*) The weight of railway tracks, if any. (For weights of same see Pars. 59, 109.)

(*d*) The snow load, if any. (For weight of same see Par. 6.)

337. Wind Pressure or Lateral Forces. (See Pars. 7, 62, 113, 114.)

338. Centrifugal Forces. (See pars. 63, 116.)

339. Traction Forces. (See Pars. 64, 115.)

340. Live Loads. (See Pars. 9, 10, 60, 110, 111.)

341. Impact. An impact allowance shall be added to the computed maximum live-load stresses, as follows:

(*a*) For floors of schools, theaters, churches, armories, dancing or other public halls and factories.... $\text{Impact} = S\left(\frac{100}{L+300}\right).$

(*b*) For floors carrying moving machinery for crane girders and posts; for highway bridges.................. $\text{Impact} = S\left(\frac{200}{L+300}\right).$

(*c*) For railroad bridges . ... $\text{Impact} = S\left(\frac{300}{L+300}\right).$

where S = computed maximum live-load stress, moment or shear,
L = length of span in feet, or loaded length of span, whichever gives a maximum.

No impact allowance shall be added to stresses produced by traction, centrifugal, and lateral or wind forces.

Calculation of Stresses

342. General Dimensions. The following dimensions shall first be calculated or assumed:

Span of slabs, supported at ends, clear opening plus thickness of slab.

Span of slabs, continuous, c. to c. of beams.

Span of beams and girders, c. to c. of support.

Length of columns, the maximum unsupported length.

343. Assumptions:

(*a*) The ratio of the modulus of elasticity of steel (E_s) to the modulus of elasticity of concrete (E_c) shall be taken at 15, or $E_s \div E_c = 15$.

(b) The modulus of elasticity of concrete in compression is constant, and the relation of stress to strain in concrete is rectilinear.

(c) In calculating the moment of resistance of slabs, beams, or girders the tensile value of the concrete shall be neglected.

344. **Bending Moments.** The bending moments shall be computed as follows:

(a) For slabs, reinforced in one direction only,

When supported at both ends, $M = 1.5wL^2$, at center
$= 0$ at ends

When supported at one end, continuous at other $\Big\}$ $M = 1.2wL^2$, at center

$$= \begin{cases} 0 \text{ at one end} \\ -1.2wL^2 \text{ at the other.} \end{cases}$$

When continuous, or fixed at both ends, $\Big\}$ $M = wL^2$, at center,
$= -wL^2$ at ends,

where M = bending moment in inch-pounds;
w = dead or live load in pounds per linear foot, uniformly distributed;
L = length of span in feet. (Par. 342.)

(b) For slabs whose length does not exceed $1\frac{1}{4}$ times their width and which are reinforced in both directions, the loading shall be assumed to be divided between the transverse and the longitudinal systems, as follows:

Ratio of long to short side............	1	1.1	1.15	1.2	1.25
Proportion of loading carried by transverse system......................	0.50	0.59	0.64	0.67	0.71
Do. by longitudinal system............	0.50	0.41	0.36	0.33	0.29

and shall be distributed to the supporting beams in a variable ratio, increasing toward the center as the ordinates of a triangle.

(c) For beams and girders the bending moments shall, aside from loading, depend upon the end conditions, as given above, under (a).

(*d*) For slabs or beams, continuous over two spans only, or for concentrated loads, or other unusual conditions, the moments and shears shall be obtained by the "Theorem of Three Moments."

345. Resisting Moments:

(*a*) In any slab, beam, or girder reinforced for compression the resisting moment of the steel in compression shall equal the compressive value of concrete×15×its lever arm. (Par. 348*b*.)

(*b*) In T-beams, where adequate bond between slab and web of beam is provided, the resisting moment of the top flange of the beam may include an adjacent part of the slab. This tributary part of the slab shall be limited as follows:

To be available the minimum thickness of slab shall be one-thirty-second ($\frac{1}{32}$) of the slab span.

The total effective width shall not exceed one-fourth ($\frac{1}{4}$) of the span length of the beam, or two-fifths ($\frac{2}{5}$) of the slab span, or 8 times the thickness of slab plus the thickness of web.

(*c*) In T-beams, where the neutral axis falls below the slab, the resistance of the web shall be neglected.

346. Reinforced Columns. Provision must be made in reinforced columns for eccentric loading, if any, and for flexure whenever the maximum unsupported length of same exceeds 18 diams. (Par. 348, *c*2.)

Proper provisions must also be made at the bottom of the columns for tensile stresses, if any, and for the distribution, by means of bearing plates or otherwise, of the compressive stresses borne by the reinforcement.

The live loads on columns may be reduced according to provisions in Par. 9*b*.

347. Temperature Stresses. Temperature stresses shall be calculated, where the structure cannot expand and contract freely, for a variation of not less than 50° F. (Par. 350.)

Unit Stresses

348. Normal Concrete and Structural Steel. All parts of the reinforced concrete structure shall be so proportioned that the sum of the maximum stresses from all causes shall not exceed

for normal concrete (Par. 375) reinforced by structural steel (Par. 372) the following values *in pounds per square inch,* except as modified in Pars. 349 and 350:

(*a*) *Axial tension:*

Concrete....................................	none
Steel, net section	15,000 lbs. (40%)

(*b*) *Bending:*

Concrete in tension	none
" " compression, generally	600 lbs. (30%)
" " " , on bottom side of continuous beams near support	700 " (35%)
Steel in tension	15,000 " (40%)
" compression	9,000 "

[Or $15f_c$, where f_c is the allowable stress on the concrete, given below under (*c*)].

(*c*) *Axial compression,* on the concrete:

1. Columns whose $\frac{l}{d} \leqq 18$ diameters.

1. Columns whose $\frac{l}{d} \leqq 18$ diameters..................	Up to 12 Diam.		From 12–18 Diam.	
	Lbs.	%	Lbs.	%
Plain concrete columns........................	500	25	400	20
Columns with longitudinal reinforcement only ..	500	25	400	20
" " reinforcement of bands or hoops..	600	30	500	25
" " longitudinal reinforcement of from 1–4% and bands or hoops..................	750	37½	650	32½
Columns reinforced with structural steel shapes thoroughly encasing the concrete...........	750	37½	650	32½

2. Columns whose $\frac{l}{d} > 18$ diameters.

$$f'_c = \frac{f_c}{1 + \frac{1}{1600}\left(\frac{l}{d}\right)^2},$$

where f_c = allowable unit stress, given above for columns of 12 diameters;

l = unsupported length of column in inches;

d = least width, or diameter, of effective area of column in inches. (Par. 359.)

3. *Axial compression*, on the steel.

Rods, shapes, or built-up members, when reinforcing the concrete .... $15f_c$

Shapes or built-up members when independent.

[See Pars. 12 (*c*), 65 (*c*), 117 (*c*).]

(*d*) *Shear*, on the concrete.

1. Direct shear only (i.e., shear uncombined with either tension or compression) for:

Beams, having no web reinforcement.......	40 lbs. (2%)
" , " bent-up reinforcement......	60 " (3%)
" , " web reinforcement of bent-up bars and stirrups	120 " (6%)

2. Shear and compression combined, equal amount of each	One-half of compression values given above under (*c*).
3. Shear and compression combined, other ratios	Interpolate between values given under (*d*) 1, and (*d*) 2.

4. *Shear*, on the steel (any grade)......	10,000 lbs.
(*e*) *Diagonal tension*, on the concrete	40 " (2%)
" " , on the steel	15,000 " (40%)
(*f*) *Bearing*.	
Concrete on concrete (equal areas)....	500 " (25%)
" " " (less area on greater area)	600 " (30%)
(*g*) *Bond* between	
Concrete and plain reinforcing bars ..	80 " (4%)
" " drawn wire............	40 " (2%)
" " deformed bars (variable)	100–160 " (5–8%)

349. Other Concretes and Steels. For concretes, differing in strength or proportion of aggregates from normal concrete (Par. 375), substitute for values given above (Par. 348) their ultimate strength in 28 days times percentages as indicated, the maximum increase over same being limited to 25 per cent.

For steels, differing in strength from structural steel grade (Par. 193), substitute for tensile values given above (Par. 348)

40 per cent of their strength at the yield point, as determined by tests.

350. **Maximum Stresses.** When combining the temperature stresses with stresses due to all other causes, the specified unit stresses (Pars. 348, 349) may be increased 10 per cent, provided that this combination gives a greater sectional area.

Design of Structure

351. **General Proportions:**

(*a*) The total thickness of a slab shall not be less than one-thirty-sixth ($\frac{1}{36}$) of the slab span in the direction of the principal reinforcement, or less than 3 in.

(*b*) The minimum width of web, in beams or girders, shall not be less than one-twenty-fourth ($\frac{1}{24}$) of the span. (Par. 342.)

(*c*) The maximum diameter of reinforcing rods, in slabs, beams or girders, shall not exceed one-two-hundredth ($\frac{1}{200}$) of the span.

352. **Continuous Spans.** Where continuity of spans, or fixed ends, are depended upon and allowed for in determining the bending moment at center, the slab or beam must be properly reinforced over the supports to resist the negative moment.

353. **Bond Strength.** Ends of plain reinforcing bars must be secured against slipping, either by depending upon the bond, in which case the length of the free end shall be not less than 48 diams. of the rod, or by bending the free end through 180° to a radius of 4 diams. of rod, or by an anchorage consisting of the free end being upset and provided with a nut and a washer. The free ends of stirrups may, at points where the beam has no top reinforcement, be turned closely through approximately 360° for this purpose. At points where top reinforcement exists the free ends of the stirrups shall pass over the same before being so turned, or shall be wound around the bars approximately one and one-half ($1\frac{1}{2}$) turns.

354. **Web Reinforcement.** After deducting the shear or diagonal tension carried by the concrete (Par. 348*d*, 348*e*) the remainder shall be carried by reinforcement consisting of bent rods or stirrups, or both. The stirrups shall be properly secured against slipping. (Par. 353.)

355. Special Reinforcement:

(*a*) Rectangular slabs reinforced for strength in one direction only shall be reinforced in the other direction, to prevent shrinkage cracks, by rods not less than $\frac{3}{8}$ in. in diameter, placed above the main reinforcement and spaced not more than 2 ft. c. to c.

(*b*) Similar slabs, designed for concentrated loads, shall be reinforced perpendicular to the main reinforcement by rods $\frac{3}{8}$ in. in diameter, spaced not more than 1 ft. c. to c., to distribute such loading.

(*c*) Slabs, beams, or girders having construction joints (Par. 362) shall be provided with shearing rods proportioned to transmit shear due to any partial loading. The diameter of such shall not be less than $\frac{3}{8}$ in., the length shall not be less than 96 diameters, the spacing shall not exceed 2 ft. c. to c., and they shall be placed near the top.

(*d*) Reinforcement against leakage cracks, when waterproofing (Par. 360), shall be distributed evenly over the entire affected area and shall consist of rods not less than $\frac{3}{8}$ in. in diameter spaced not over 18 in. c. to c. in two directions perpendicular to each other.

(*c*) Reinforcement for temperature stresses (Par. 347) shall be distributed over the entire area of the cross-section in a ratio varying with the same.

356. Splicing of Reinforcement. Wherever it is necessary to splice the reinforcement the rods in tension shall be connected by a direct splice of a strength equal to that of the rod, or by overlapping their ends. The length of lap in diameters shall not be less than the total stress in the rod, at point of splice, divided by 300. In compression, where reinforcing rods over 1 in. in diameter are joined, they shall be butted and fully spliced; rods of smaller diameter may be lapped as in tension.

No splices shall be made at points of maximum stress.

357. Minimum Reinforcement. The minimum reinforcement in slabs, beams or girders shall not be less than three-fourths of 1 per cent ($\frac{3}{4}\%$) of the effective area of the concrete; in columns with longitudinal reinforcement only not less than 2 per cent and in columns having circumferential reinforcement such reinforcement shall not be less than 1 per cent of the effective area.

358. Spacing of Reinforcement:

(a) *Slabs* The minimum spacing of parallel bars shall not be less than 3 in. Two layers of bars perpendicular to each other shall be in contact, the bars forming the main reinforcement being in all cases placed undermost.

(b) *Beams and Girders.* The minimum distance from the center of any bar to the edge of beam shall be 2 diameters, or 1½ in. The minimum distance c. to c. of any bar in the same layer shall be 2½ diameters for round bars and 3 diameters for square bars, and not less than 2 diameters between centers of bars in different layers. The longitudinal spacing of stirrups or bent rods, where used, shall not exceed three-fourths (¾) of the depth of the beam.

(c) *Columns.* In columns having longitudinal reinforcement only, the rods shall be securely tied together at intervals not exceeding 20 diameters of rods. In columns having circumferential reinforcement the clear spacing of such shall not exceed one-fourth (¼) the diameter of the inclosed column.

The circumferential reinforcement shall be securely held in position by means of spacing bars, or other adequate means.

359. Fireproofing. The minimum thickness of a fire-retarding coating, covering the reinforcement, shall be as follows:

For slabs,	not less than	1½	diams. of rods, or	¾ inch
" beams,	"	1½	"	, or 1½ "
" girders,	"	1½	"	, or 1½ "
" columns,	"	1½	"	, or 1½ "
" columns having no reinforcement,				2 "

The above coverings shall not be considered as effective area; they shall be made of concrete in which no limestone is used, but in which the coarse aggregate may consist of hard-burned cinders or other material that will resist high temperatures. All aggregates shall be so small that the reinforcement is thoroughly covered, leaving no voids or cracks.

For further fire-resisting purposes all external angles shall be either beveled or rounded.

360. Waterproofing. Waterproofing shall be effected by using a concrete of maximum density in connection with special reinforcement to prevent leakage cracks (Par. 355*d*), or by a waterproof coating, or by addition of an approved waterproof compound.

The proportion of aggregates to be used in obtaining such concrete shall be determined for each case by experiments.

The waterproof coating shall generally consist of from 4 to 8 layers of a strong flexible felt or cloth fabric, so treated in manufacture that all pores are closed, cemented together with specially prepared preparations of asphalt, coal tar or coal-tar pitch, or of a thick layer of a similar bituminous compound applied as a mastic, upon the surface after being troweled off with cement mortar. (Par. 377.)

361. Weatherproofing. Concrete may be rendered weatherproof, even waterproof under moderate pressure, by applying alternate washes of aluminum sulphate and soap, or by a wash of cement grout. These washes shall be applied by a soft brush after the surface of the concrete has been thoroughly cleaned.

362. Construction Joints. Construction joints in reinforced concrete shall, whenever unavoidable, be located as follows:

In slabs and beams, near the center of the span.

In girders near the center of the span, except when another girder or beam joins at this point.

In such case the joint shall be offset a distance equal to the depth of the girder and shall be reinforced for shear if necessary.

In columns horizontal joints shall preferably be made flush with the lower side of the girders, or the upper side of the floor line.

All construction joints in slabs, beams, girders, or columns shall be perpendicular to the plane of their surfaces.

363. Expansion Joints. In exposed work, when not fully reinforced for temperature stresses, special expansion joints shall be provided at intervals usually not exceeding 75 ft. Guides for cracks shall be provided at distances to be approved by the Engineer.

Expansion joints shall interlock, wherever practicable, usually by tongue-and-groove joints in the concrete, reinforced by

short steel rods embedded with one end in the concrete, and free to slide with the other in embedded gaspipe.

Materials and Workmanship

364. **Cement.** The cement shall be Portland, either American or foreign, which will meet the requirements of the standard specifications adopted by the American Society for Testing Materials. (See Part VIII.)

365. **Fine Aggregates.** Fine aggregates are sand and screenings of either gravel or crushed stone. They shall be graded in size up to such grain which, when dry, will pass a screen having ¼-in. meshes.

366. **Coarse Aggregates.** Coarse aggregates most suitable for reinforced concrete structures are gravel, broken stone, and hard-burned cinders. They shall be screened and of such size as will be retained on a screen having ¼-in. meshes, but will pass a ¾- or 1-in. mesh, the smaller aggregate being used in the fire-retarding coating covering the reinforcement. (Par. 359.)

367. **Sand.** The sand shall be clean, coarse, and of grains varying in size. It shall not contain clay or loam to the extent of more than one-half (½%) per cent and shall be free from any other foreign matter.

368. **Gravel.** The gravel shall be composed of reasonably clean pebbles of hard and durable stones of sizes not exceeding ¾ in. in diameter, free from clay and other impurities. To maintain the proper proportions in the concrete mixture it shall be screened and divided into fine and coarse aggregate. (Pars. 365, 366.)

369. **Stone.** The stone shall be clean, sound, hard, durable, and free from all foreign matters, crushed or broken to sizes not exceeding 1 in. in diameter. Only such stones as will break in approximately cubical pieces shall be used; those, like slate or shale, which break in thin flat pieces, shall be rejected. To maintain the proper proportions in the concrete mixture it shall be screened and divided into fine and coarse aggregate. (Pars. 365, 366.)

370. **Cinders.** Hard-burned cinders may be used as the coarse aggregate of a fire-resisting coating. (Par. 359.) They shall be

composed of hard, clean, vitreous clinker, free from sulphides, unburned coal, or ashes.

371. **Water.** The water shall be clean, free from oils, acids, strong alkalies, or vegetable matter.

372. **Metal Reinforcement.** The reinforcement shall preferably consist of structural steel conforming to the specifications adopted by the Association of American Steel Manufacturers, 1910. (See Part V, Pars. 192 to 201.)

In general round bars are preferable to square bars. Deformed bars of hard steel and cold-twisted bars may be used in special cases.

For the prevention of shrinkage cracks, leakage cracks, and as reinforcement for temperature stresses, or for minor details, the bars used need not be tested. All other bars shall be tested.

373. **Proportions.** The proportion of the materials in the concrete and the percentage of the reinforcement shall be specifically stated in the contract.

The aggregates used in the concrete shall be carefully selected, of uniform quality and proportioned so as to secure as nearly as possible a maximum density.

In ordinary work the proportions may be selected according to judgment based upon experience; but in important work, or where waterproofing is required, the correct proportions for maximum density shall be determined in each case by experiments.

374. **Unit of Measure.** The unit of measure shall be the barrel, which shall be taken as containing 3.8 cu. ft. and shall contain 376 lb. of cement net. A bag of cement shall contain 94 lb. of cement net.

375. **Normal Concrete.** For reinforced concrete work "normal concrete" shall be composed of 1 part Portland cement and 6 parts of aggregate, approximately 2 parts of fine and approximately 4 parts of coarse aggregates, which shall be measured separately—capable of developing an average compressive strength of 2000 lb. per sq.in. in 28 days, when tested in cylinders 8 in. in diameter and 16 in. long, under laboratory conditions of manufacture and storage, using the same consistency as is used in the field.

376. **Other Concretes.** The strength and suitability of concretes, other than normal concrete, for reinforced concrete

work will depend upon the richness or the leanness of the mixture and the character of the aggregates.

The structural value of such concretes shall be based upon the average compressive strength in 28 days, as determined above for normal concrete. (Par. 375.)

377. Cement Mortar. Cement mortar, used in reinforced concrete work, shall generally be composed of 1 part Portland cement and from 2 to 3 parts of fine aggregates. The mortar shall be mixed by hand. (Par. 330.)

378. Cement Grout. Cement grout, used in reinforced concrete work, shall be composed of neat Portland cement mixed with water to a consistency of thick cream or whitewash.

379. Workmanship:

(*a*) All material and labor shall be of the best quality in every respect and shall be subject to inspection and approval at any time during the progress of the work.

(*b*) The entire work shall be constructed in a substantial and workmanlike manner, and to the satisfaction and acceptance of the Engineer. (Par. 383.)

(*c*) The contractor shall employ skilled or suitable mechanics and laborers for every kind of work and shall, at the request of the Engineer, discharge any workman whom he deems incompetent, negligent, or untrustworthy.

380. Facing. (See Par. 318.)

381. Finishing:

(*a*) The finishing of the surface shall be determined before the concrete is placed and the work conducted so as to make possible the finish desired.

(*b*) After the forms are removed any small cavities or openings in the face shall be neatly filled with cement mortar, if necessary in the opinion of the Engineer. Any ridges due to cracks or joints in the lumber shall be rubbed down with chisel or wooden float.

(*c*) When desired the face may be covered with a finish of a thin grout, or a whitewash, applied with a brush. Plastering shall not be applied to any face exposed to the weather.

(*d*) Before the concrete has thoroughly set the face may be treated with a wire brush; after having hardened with a soft brick, with hand or pneumatic tools.

(*e*) A colored finish may be obtained by using naturally colored aggregates, or by adding a mineral pigment of any desired shade when mixing the concrete, as may be determined by the Engineer.

INSPECTION AND ERECTION

382. Inspection. Inspection during construction shall be made by competent inspectors employed by, and under the supervision of, the Engineer, and shall cover the following:

(*a*) The materials.

(*b*) The correct construction and erection of the forms and the supports.

(*c*) The sizes, shapes, and arrangement of the reinforcement.

(*d*) The proportioning, mixing, and placing of the concrete.

(*e*) The strength of the concrete by tests upon standard test pieces made on the work.

(*f*) The protection of the work against frost, the sun and the weather generally.

(*g*) Whether the concrete is sufficiently hardened before the forms and supports are removed.

(*h*) Prevention of injury to any part of the structure by and after the removal of the forms and shores.

(*i*) Comparison of dimensions of all parts of the finished structure with the plans.

383. Accepting Material or Work. If the inspector, through an oversight or otherwise, has accepted material or work which is defective or contrary to the specifications, the material or work, no matter in what stage of completion, may be rejected by the Engineer.

384. Testing the Structure. Load test on any part of the finished structure shall be made where, in the opinion of the Engineer, there is a reasonable suspicion that the work has not been properly performed, or that, through influences of some kind, the strength has been impaired, and may be made in any case.

The test load applied shall not exceed that which will cause a total stress in the reinforcement of three-fourths ($\frac{3}{4}$) of its strength at the yield point, or more than twice the superimposed load.

The test load shall be left on the part under test for 24 hours, shall not cause a deflection exceeding one-four-hundred-and-eightieth ($\frac{1}{480}$) of the span, shall show no sign of cracks, and shall leave no permanent deformation.

Load tests shall not be made upon arches until after 90 days, or upon other structures until after 60 days, of hardening.

385. Erection:

(*a*) Whenever the contractor is required to remove any existing structure, to clear the site, or to excavate, such requirements shall be specifically stated in the contract.

(*b*) Otherwise the erection shall include all necessary hauling, the unloading of the materials and their proper care until the completion and acceptance of the work, as specified in Pars. 385*c* to 391.

(*c*) The contractor shall furnish, at his own expense, all necessary staging, falsework, materials, and tools, and shall erect the structure complete and finish the same as specified in the contract. (Par. 390.)

386. Removal of Old Structure. Whenever new structures are to replace existing ones the latter shall be carefully taken down and removed by the contractor to some place specified in the contract.

387. Interruption of Traffic. All operations shall be so conducted as not to impede or interrupt the work of other contractors, the traffic of any railroad, nor close any thoroughfare or waterway, nor conflict with any law, regulation, or ordinance of any properly constituted authority.

388. Permits. Before commencing operations the contractor shall, at his own expense, obtain all necessary permits and comply with their requirements.

389. Safeguards and Damages. The contractor shall furnish, at his own expense, all watchmen, guards, signals, night lights, etc., for the prevention of accidents, and be responsible for the safety of the structure; and he shall assume full responsibility for all accidents to men, animals, and materials before the completion and final acceptance of the structure and shall indemnify its owner for any and all claims for damages arising therefrom.

390. Defective Work. The contractor shall, at his own

expense, remove, rebuild, or make good any damaged material or defective work, even if same through an oversight or otherwise has been previously accepted.

391. **Clearing up.** When the erection is completed the contractor shall, at his own expense, remove all falsework, rubbish, and other useless material caused by his operations.

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